REBUGGING THE SMART CITY

Design Explorations of Digital Urban Infrastructure

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Abstract. Smart Cities are presented as a straightforward solution to diverse urban problems. On a closer look, however, the discourse on 'Smart Cities' seems wicked in various ways: vaguely defined, speculative, and fragmented into incommensurable positions. Focussing on this 'wickedness,' we explore the potential of design approaches to pervade the obscurities and discursive segregations around digital urban infrastructure. Insights from critical design theory lead us to an engagement with digital design not only as validation and enhancement of Smart City projects but as contingent and political exploration. Design becomes an investigation and remaking of what a 'Smart City' means in a concrete context. Hence, this approach allows an intersection of social and technical, affirmative and critical perspectives. We explore this approach through an experimental workshop. Hence, we discuss the unfolding of two design engagements: the reframing of 'Smart Lighting' as cosmopolitical controversy and the hacking of pedestrian navigation as urban exploration. This approach shows a double potential: On the one hand, it makes digital design practices aware of their ambiguous and political effects. On the other, we scrutinise the possibility of sociotechnical design perspectives as a research approach towards 'Smart City' projects and digital urban infrastructure.

Keywords. Smart City; Design Theory; Prototyping; Digital Infrastructure; Urban Studies; Critical Making; Speculative Design; SDG 9; SDG 11.

1. Introduction

'By 2050, half of the world's population will live in cities, and cities cause most of the world's CO2' (or similar) precedes most *Smart City* (henceforth: SC) research as a fateful preamble. Following this urgency, optimising such future cities and mitigating disastrous effects seems inevitable. Municipal and corporate-led projects promote the

potential of technical innovations regarding social, ecological, and economic issues. 'Sustainable Cities and Communities' are envisioned through technology and infrastructure. Conversely, urban scholars question this simplistic attitude towards complex urban problems (e.g., Marvin et al., 2016). However, both critical and affirmative approaches often remain in 'technological determinism,' either praising or condemning the SC generically (Farías & Widmer, 2018, p. 44). Using the term 'Ordinary Smart Cities,' Farías and Widmer suggest 'decentering' this discussion towards a more contextual and contingent understanding of how SC projects remake urban environments (ibid.). Hence, SC projects are not only confronted with urban complexity but become a part of it. Instead of a univocal and omnipotent solution, the SC itself resembles the 'Wicked Problems' described by Rittel and Webber (1973). Literally, it seems 'ill-defined,' involving heterogeneous aspects such as ISO-norms, governance practices, everyday activities, and digital networks. Thus, the SC entails diverse socio-political conflicts, while its realisation remains vague between actual implementation and wild speculation. This makes it challenging to follow what a SC means within a specific context and how it remakes urban environments.

Rittel and Webber describe 'design' as the reflective practice of exploring, framing and reframing such complex problems (1973). Building upon this perspective, we explore the potential of design approaches to investigate and remake the sociotechnical arrangements of the SC. Instead of planning digital infrastructure as direct 'solutions' regarding specific sustainable development goals, we consider (digital) design as a critical perspective to deconstruct such imperatives and analyse how these goals are negotiated and contextualised within SC projects. The metaphor of 'rebugging' becomes our narrative to engage with friction, contingencies, and possible alternatives through experimental design activities. This paper discusses how (digital) design practices allow new insights regarding two related questions: What is a SC? And what could it be?

On the one hand, we discuss how design practices contextualise the SC in concrete urban contexts. Could design intersect incommensurable perspectives, like affirmative and critical arguments, political and technical engagements? How do SC projects intertwine social practices, political controversies and infrastructure?

On the other hand, we investigate design as an open-ended or even speculative practice, through which we explore contingencies, tensions, and friction within digital infrastructure. How could designing remake monodirectional optimisation as a contingent and political field? Discussing the possible trajectories of SC projects seems crucial regarding the dynamic development of this domain.

We investigate these questions following an experimental workshop. Firstly, we survey perspectives from critical design theory to reconsider (digital) design as a critical approach towards the SC. Thus, we explore how insights from design theory allow a combination of technical engagements and critical perspectives. We describe the unfolding of this approach through two design engagements emerging in the workshop. Thus, we explore how these design activities frame, contextualise, and remake a SC. Finally, we discuss the potential of (digital) design practices to engage with the complex sociotechnical configurations of SC projects. Furthermore, we scrutinise how this sensitivity makes the design of digital urban infrastructure and SC projects more attentive to the contexts and conflicts they are involved in.

2. Designing, Making and Fabulating Smart Cities

Design thinking, participatory projects, and experimental prototyping can be considered a key 'modus operandi' of many SC initiatives (Tironi & Criado, 2015). Nonetheless, these activities do not lead a priori to a critical engagement. Tironi argues that prototyping often follows a simplistic 'validating' rationale instead of exploring contingencies and conflicts. Thus, SC projects are only considered solutions to urban complexity, whereas their inherent 'wickedness' is neglected. However, Tironi continues, these processes may still generate unexpected responses and frictions, which are worth analysing (Tironi, 2020). So how to consider design as the open exploration of these contingencies instead of a strategy to solve wickedness?

While McFarlane and Söderström criticise context-ignorant, 'post-political,' economy-centred, and technocratic tendencies of SC initiatives (2017, p. 313), Rosner counters similar problems within the domain of design (2018). Reframing design as 'Critical Fabulation,' she suggests focussing on contingencies, situated knowledge, collaboration and the continuous challenging of presumptions (Rosner, 2018, pp. 184–186). This perspective resonates with approaches at the intersection of Science-Technology-Studies and design theory. Variations of 'Making,' 'Design,' and 'Prototyping' combine critical perspectives with material and technical engagements (Varga, 2018). For instance, Ratto describes 'critical making' as a process-oriented collaborative investigation instead of the search for a single solution. He suggests the reciprocal combination of concrete technical experimentation and theoretical discussions. Hence, 'critical making' attempts to resolve the dilemma of 'innovation' vs 'critique' by 'reintegrat[ing] technical and social work and thereby innovat[ing] both.' (Ratto, 2011, p. 258)

However, this synthesis of critique and innovation should not enforce false consensus over controversial problems. Varga demonstrates how design perspectives invoke a plurality of political engagements: materially inscribed 'subpolitics' in the sense of Foucault; controversies arising around artefacts following Latour; or as the composition of a common world through Stenger's 'cosmopolitics' (Varga, 2018, pp. 33–35). Designing becomes a critical activity that deconstructs presumptions, discovers controversies, and slows down to recompose an urban cosmos. For scholars like Wilkie, designing represents a speculative method to explore possible political trajectories of digital technologies (2015). According to Di Salvo, the engagement with prototypes becomes not only a form of inquiry but a potential to confront and remake problematic conditions (2014).

Scholars like Tironi (2018) or Hollands (2015) discussed experimental prototyping to reframe the SC as context-specific, participatory, and knowledge-based. However, these studies mostly stay vague on the role of digital infrastructure within this remade 'Smartness.' While these approaches represent a crucial intervention into a technology-dominated discourse, we consider the concrete disposition of digital infrastructure as a relevant part of broader and 'societal' discussions around the SC. Hence, we aim to complement these perspectives through a concrete engagement with digital technologies. Building upon the introduced approaches, we discuss the potential of digital design to draw relations between technical and sociopolitical dimensions of the SC, juxtapose critical and affirmative perspectives, and combine analysis with speculative trajectories.

3. Investigating the Smart City by Remaking the Smart City

A workshop with a small group of Master level students from Architecture and Landscape Architecture at the Technical University of Munich became an opportunity for this experiment. The workshop was introduced by an intense research phase of three days, followed by three months of project development. This format allowed a playful investigation of digital urban infrastructure based on the described methods. It introduced mapping, reverse-engineering, and prototyping activities to generate a concrete understanding of digital urban infrastructure, intervene speculatively, and explore unexpected trajectories. While we carefully planned a structure of different methods, we were open to contingencies and dynamics. Instead of focussing on final results, this paper follows the workshop process through a series of design engagements.

Though, how to approach a wicked SC? Whereas Ratto (2011, p. 253) suggests combining technical making with critical research and discussions, the first open question was where to start these activities. The discourse on SCs invokes a multitude of topics and heterogeneous topologies, from class diagrams to urban spaces, everyday practices, and infrastructure networks. Furthermore, digital urban infrastructure often seems abstract, immaterial, and context-less. SC projects appear in different states of realisation, ranging from almost banal implementations to Sci-Fi speculation. Inspired by Rittel and Webber, we introduced designing as a practice of framing and reframing what *'Smart City'* pragmatically means. Initially, a series of speculative mapping tasks were introduced as a design-based exploration of the SC and its involvement in urban environments.
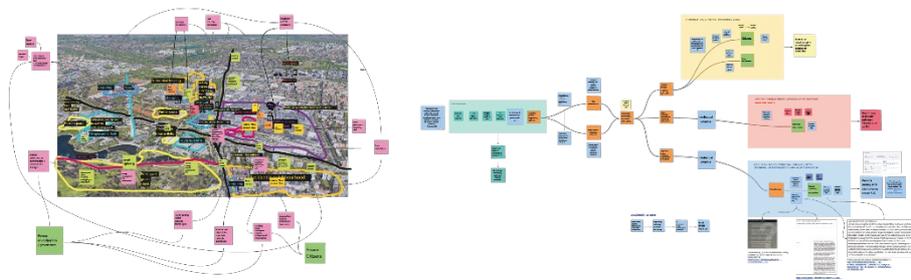

Figure 1: Spatial Mapping and Infrastructural Mapping

The participants started mapping a selected urban area. They gathered spatial patterns, activities, and infrastructure as a collage of existing maps, diagrams, and sticky notes. They researched different SC projects and discussed how these would integrate into the observed spaces. The resulting cartography served as a first 'mapping' of what a SC means in the local context (see Figure 1, at the left). Hence, the map became a speculative tool to contextualise and relate diffuse definitions, speculative projects, and abstract technologies.

Consecutively, the participants focused on one digitally transformed practice or infrastructure in this map. By this, we turned towards the disposition of digital

infrastructure and its entanglements in urban environments. The participants scrutinised the observed system and created a plan of its components, processes, and media. Inspired by the mapping project 'Anatomy of an AI System' (Crawford & Joler, 2018), they discussed how the analysed infrastructure reconfigures spaces, generates conflicts and becomes political. Thus, digital infrastructure is interpreted as a 'matter of concern,' which interconnects various urban controversies (Latour, 2007, p. 815). Maps of Smart Parking, Energy Grids or Crowd Monitoring emerged and related heterogeneous perspectives like class diagrams and claims for a 'right to the street' (see Figure 1, at the right). While these maps showed that digital technologies are neither abstract nor separated from political questions, we wondered how to explore this dimension in more detail and move beyond a dichotomic projection of technology on space or politics on technology.

Hence, we encouraged the participants to choose one situation in their mappings and rearticulate it through a design intervention. After the initial block phase, these experiments were developed through longer and less structured design experiments, accompanied by drawing storyboards, making conceptual prototypes, and open discussions.

3.1. SMART LIGHTING COSMOPOLITICS

The first discussed project examined the digital transformation of urban lighting. The initial mapping showed street lanterns in heterogeneous spaces such as parks, parking lots, highways and residential streets. These lanterns were involved in diverse urban activities, from traffic to nightly table tennis. Enhancing streetlights represents a prominent use case for various SC initiatives. Technical research on 'Smart Lighting' revealed how digital infrastructure addresses the maintenance, control, and monitoring of street lanterns. Lighting infrastructure is enhanced through sensors, communication networks, and control mechanisms (M. Castro et al., 2013). The technical mapping showed how digital infrastructure reconfigures the circulation of energy, light, control signals, exchanged light bulbs, and sensor data. Additionally, this investigation revealed diverse problems addressed through 'Smart Lighting:' saving energy, enhancing the durability of light bulbs, improving maintenance efficiency, or enhancing the security of nightly streets.

Despite this diversity of problems, the examined 'Smart Lighting' projects followed the monodimensional rationale of enhancing positive effects (e.g., maintenance efficiency) while reducing negative impact (e.g., resource consumption). However, these clear design goals seemed far less unambiguous on closer examination. For instance, the implied correlation of light and safety turned out more fragile than expected: 'Walking through a dark park, does light make you secure or perhaps exposed?' Being lit up may not entail the same safety for everybody in every situation. This point was discussed with historical reference to the 18th century 'Lantern Laws,' which made urban lighting an infrastructure of racist oppression. (Browne, 2015). Another discussion thread addressed which needs and interests are considered within an automatically controlled lantern network. On the one side, discussing how SC projects reconfigure urban light became a reverse-engineering of hidden 'subpolitics' in the sense of Foucault (Varga, 2018, p. 33). On the other side, the question of who and what to take into account led the project to cosmopolitics in the sense of Stengers

(2005). Thus, the project asked how urban lighting co-creates specific urban atmospheres, which enable particular activities and frustrate others – lingering, walking quickly, jogging, feeling safe?

Leonie, who conducted this project, chose the problem of light regulation as a design brief. She rearticulated these logics of urban lighting to explore their presumptions, effects, and politics. How could this prototype investigate the involved rationales, actors, practices, and interests? The first concept (see Figure 2) introduced a light-jukebox as a metaphorical controller, which allows a tuning of the atmosphere by various actors. While this attempt seemed promising in general, it still involved a commodified and human-centred perspective, which seemed not to do justice to the environmental implications of light.

Figure 2: Storyboard of a Remaking of Smart Lighting
*(Image by Leonie Lux)*

The next concept targeted opening the jukebox towards unexpected actors and incommensurable input. Designing the interactions of this experimental 'Smart Lighting' system became an investigation of *what* and *who* to take into account and *how* to frame the problem of light concerning human usages, safety, resource usage, and the affected fauna. We discussed how to inscribe these different perspectives into the digital control of urban light. The debate revolved around wildlife sensing, youngsters kicking out lanterns, and Dumbledore's deluminator. Finally, the proposal for a process-oriented prototyping project emerged. A few smart home light bulbs would be installed in a park near the university. Their brightness, light colour and animation are modulated through a simple micro-controller. The prototype's interface and control logic would be adapted successively in reaction to the local environment. Thus, the lighting system becomes successively attuned to unexpected conditions. The prototype development would trace the cosmopolitical negotiation over an atmosphere.

Probably because of the non-solutionist focus of this workshop, this promising concept remains an inspiring mock-up until now.

3.2. DIJKSTRA'S DRIFT

The second project scrutinised how the SC and digital infrastructure are involved in the walk of pedestrians. A mapping emerged from the initial tasks, laying out different digital technologies along a fictional stroll through the observed area. Thus, this map explored how sensors, databases, GIS, interfaces, and algorithms monitor and influence pedestrian movement. Technologies such as individual smartwatches and air-pollution models co-constitute the practice of *how* and *where* to walk. This collage touched diverse questions of health, safety, traffic, privacy. Ekaterina, who was responsible for this project, focused on the practice of pedestrian wayfinding for further exploration. How is the choice, where to walk, remade through air-pollution maps, traffic data, models, and algorithms?

Even though 'wayfinding' currently occurs individually and in the private sector, we did not want to delimit the discussion of what a SC means beforehand. Thus, Ekaterina investigated design interventions into the practice of navigation. A first prototype framed navigation as a negotiation among different factors instead of just the 'shortest route.' The user scenario depicted a parent and a child who playfully create a way to school which is safe and fun. A multi-criteria navigation app would support this wayfinding. A discussion emerged around this prototype: On the one hand, the 'learning' aspect and the exploration of different criteria seemed interesting. On the other, 'improving the way to school' appeared to fall into the trap of optimisation and securitisation. The prototype established a deterministic relationship between the user and digital infrastructure, child and parent. Hence, we wondered how to open this standard SC narrative up through prototyping.
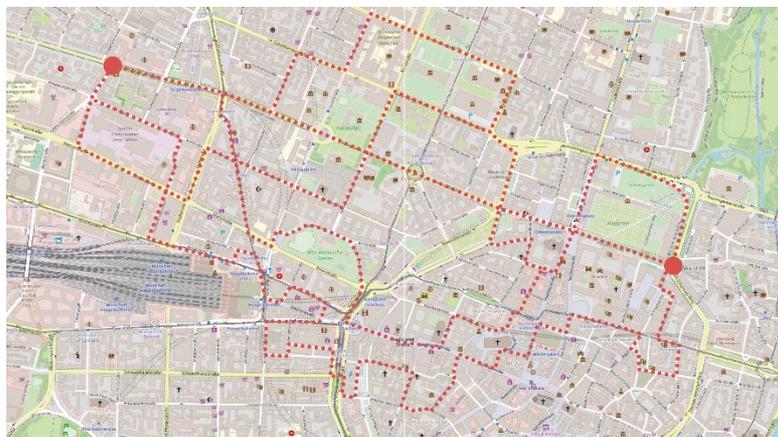
*Figure 3: Resulting Journeys of the Dijkstra's Drift
(Project by Ekaterina Tepliakova)*

Instead of a deterministic relationship, Kitchin and Dodge describe the involvement of digital technology in urban practices as a 'collaborative,' 'contingent,' and 'context-specific' 'transduction' (2011, p. 80). Following this thought, navigation becomes a sociotechnical negotiation between pedestrians and technology. This perspective resonates with de Certeau's seminal description of walking as the tactical *reaction to*

and *re-appropriation of* top-down planned spaces and infrastructure (1984).

A second prototype started with a playful investigation of Google Maps. First, the application generated connections between two places. These routes were distorted and dragged according to different criteria by mouse clicks and disobedient walking. For a more detailed insight into this interaction, Ekaterina turned towards technical wayfinding models, namely Dijkstra's Algorithm. This algorithm addresses the shortest-way problem through a weighted network graph. A cost function includes different criteria in this weighting. (Velden, 2014) In the case of navigation, these are usually distance, congestion, or simplicity.

We discussed how to reinterpret these means-to-reach-an-end as devices for urban exploration through several prototyping steps. The project took inspiration from situationist psychogeography. This playful mapping practice rearranges the structuring and understanding of urban spaces by strolling/drifting through the city (Flanagan, 2013, pp. 194–197). How could we remake navigation as drift through both physical and digital spaces?

Ekaterina experimented with different cost functions, adding weight to Dijkstra's network graph. Thus, she played with different logics to connect locations on a map: the shadiest, hottest, greenest, or most accident-ridden route (see Figure 3). By this, the data sets were experimentally related to navigation. According to these rulesets, the algorithm generated semi-absurd journeys to stroll through urban spaces. The walk along these navigation graphs was documented as video. These movies showed experiences of urban spaces, which were co-constituted by experimental navigation rules. Prototyping became an exploration of different rationales of moving through the city. On a second layer, the prototype allows exploring how these logics intersect with concrete urban spaces. Hence, it enabled the discovery of the underlying datasets in urban space. How is the experience of the 'highest ranked' way? How does it feel to wander through 'hot' climate data? The prototype recontextualises datasets and algorithms in the pedestrian's experience. Thus, the documented journey moved through both urban space and the navigation model. It remakes navigation as an open-ended exploration of the physical *and* the smart city.

4. Discussion

This paper described the implementation of SC projects in urban environments as a wicked problem and experiments with design approaches to understand and remake how SCs reconfigure urban spaces and practices. Hence, we reviewed perspectives from critical design theory. Furthermore, we explored experimental and playful design interventions in a workshop and followed two projects through several design activities. By this, we discovered the sociotechnical involvement of digital infrastructure in concrete urban environments as well as possibilities to remake these constellations. In conclusion, we discuss what insights this perspective allows and how it is relevant for an extended digital design practice.

We introduced design activities to contextualise and reframe what a SC represents in a specific context – and what problems it entails. The initial mappings and the following prototyping tasks successively connected different topologies and aspects, like technical diagrams, urban spaces, and political issues. Furthermore, these

approaches concretised abstract and speculative SC projects through sociotechnical engagements. The first prototype revealed the complex social and political entanglements of lighting infrastructure. The 'Dijkstra's Drift' intimately related the abstract network space of digital models and the pedestrian's everyday experience.

Furthermore, both projects allowed de-centring the teleological focus of digital design and exploring contingencies in the SC. Engaging with 'Smart Lighting' deconstructed the usual rationale of 'optimisation' and revealed the political dimensions of this infrastructure. The second prototype reconsidered the target-oriented function of 'wayfinding' as the exploration of hybrid urban spaces. Thus, design engagements allowed critical insights by challenging presumptions and exploring alternative trajectories. However, this criticality was not a given but emerged through design activities, from continuously intersecting technical perspectives with theoretical discussions and reacting to nagging questions. Both projects even shifted back and forth between solutionist and explorative approaches. Optimistically, we interpret this as a productive co-existence of technical and critical perspectives.

On the one side, the presented methods allowed insights into the involvement of SC projects in urban environments. Of course, these methods are not a substitute for ethnographic or theoretical investigations of the SC. Nonetheless, the described design approaches could complement such studies, offering an exploration of the sociotechnical disposition of digital infrastructure. On the other side, the discussed methods represent a valuable contribution to digital design practices in the SC context. They challenge inherent presumptions and investigate how the developed projects entail contingent effects. At least, the proposed playful approaches offer relaxation to an often tense and deterministic discourse.

Nonetheless, the presented perspectives bear various potentials for further exploration. Even if the workshop aimed to contextualise digital technologies, both presented prototypes were only loosely related to concrete urban spaces. For future work, it is essential to explore how these practices reconfigure specific urban environments and how they are affected reciprocally. While this paper focussed on experimenting with digital technologies, a stronger connection to urban contexts remains a vast potential. Also, due to the current pandemic, the collaborative and participatory aspects of the introduced design approaches fell short. However, including situated perspectives and experiences is crucial to understanding how SC projects concretely affect different groups and stakeholders. Collaboration becomes an essential aspect for the further exploration of the presented methods.

Thus, this experiment only represents our first design steps towards wicked smartness. The documented activities made us problematise and rearticulate the SC in various ways. The workshop made it move from 'By 2050…' to urban spaces, negotiations around urban light, and situationist navigation tools. Where else could design take the Smart City?

Acknowledgements

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