🏆 *reviewed paper*

The Potential of Design Thinking for Tackling the "Wicked Problems" of the Smart City

Brita Fladvad Nielsen, Daniela Baer, Savis Gohari, Eivind Junker

(Brita Fladvad Nielsen, Postdoctoral Researcher, NTNU Department of Architecture and Urban Planning, 7491 Trondheim, brita.nielsen@ntnu.no)
(Daniela Baer, Research Scientist, SINTEF Building and Infrastructure, 7491 Trondheim, daniela.baer@sintef.no)
(Savis Gohari, Postdoctoral Researcher, NTNU Department of Architecture and Urban Planning, 7491 Trondheim, savis.gohari@ntnu.no)
(Eivind Junker, Postdoctoral Researcher, NTNU Department of Architecture and Urban Planning, 7491 Trondheim, Eivind.junker@ntnu.no)

1 ABSTRACT

Cities' transition to becoming 'Smart Cities' can be seen as one of the most complex and 'wicked problems' of our time; requiring cities to be able to make use of 'bottom-up' innovation and resources while managing a transition to a more integrated way of managing cities and public private people partnerships. This transition depends upon cross-disciplinary knowledge transfer and balancing existing and new knowledge. Currently, Norwegian cities fail to balance the new (exploratory and bottom-up) and existing (exploitative) knowledge in their smart city demo projects. Balancing these and achieving 'ambidextrous innovation' is a key for open innovation. Design thinking offers an overarching approach to deal with 'wicked problems'; an approach to develop shared and user-centric understandings of the challenges of and potential scenarios for cities aiming at 'smartness'. Design thinking can address emerging challenges in the smart city paradigm, in a collaborative setting of diverse stakeholders, novel ideas and innovative approaches. Design and design thinking are abductive reasoning, seeking to identify how one can reach value-oriented goals through the combination of new connections between 'how' and 'what'. Design thinking looks for ways to work with a 'designerly' mindset, and to unlock innovation potential through the application of different methods and processes. Design thinking can therefore help to develop a common understanding of smart cities and communities and its inherent core values, as has been demonstrated by three experiments discussed here. Design thinking was applied to wicked smart city problems in three Norwegian cases in Oslo, Bergen and Trondheim. In the three different cases we deal with the issues of smart energy, smart participation and smart mobility. Through an analysis of the three cases we show that design thinking can result in concepts, products or new insights, and we categorize which types of knowledge a design thinking approach can generate. We show that design thinking can generate knowledge relevant for a conscious and structured open innovation process needed to transition in to smart cities in a way that makes sense. The knowledge acquired set directions for how to bridge existing approaches and tools of municipal planning, with new future scenarios and pitfalls of the smart city.

Keywords: urban design, smart cities, knowledge management, design thinking, open innovation

2 INTRODUCTION

Planning problems are wicked problems due to the inherent uncertainty, complexity and inevitable normativity (Hartmann, 2012; Rittel & Webber, 1973). A wicked problem is one, which there is no final solution for, but a complex and fuzzy one. Wicked problems are a "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing (Churchman, 1967). The smart city approach as the smart use of technology, management and policy is emerging to solve such tangled and wicked problems inherited in the rapid urbanization (Goodspeed & Society, 2014; Nam & Pardo, 2011). The opportunities of the 'smart city' adds expectations for cities to transition into a new technology paradigm fast, yet the involved stakeholders have different interpretation and most cities and nations lack clear goals and strategies. Cities, municipal planners and other urban decision makers are therefore required to find ways for balance/exploit the existing knowledge of the involved stakeholders and realize new opportunities (B. F. Nielsen, Baer, Lindkvist, & Change, 2018). How the development of a smart city can contribute to improve society has itself become one of the most complex and 'wicked' problems of our time.

This paper follows the holistic trajectory of smart cities theory(B. F. Nielsen et al., 2018) and agrees that for a city being truly smart, improving just one part of an urban ecosystem does not imply that the wicked problems of the whole are being solved (Nam & Pardo, 2011). Indeed, the combination, connection and

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

integration of all urban aspects (technical, institutional, legal, economic, environmental and social) are fundamental. This implies that a smart city approach is not only about application of smart technologies, but an integrated, encompassing approach to address urban challenges and to bring about sustainable and resilient development to improve the quality of life of citizens. If the smart city represents the final goal of such a virtuous path, a multi-stakeholder and user-centric

approach is needed to understand wicked urban issues from the citizens' and end-users' perspective and engagement. Accordingly, the smart city should imply a comprehensive approach to city management and development, where human and social capital interact, and technology-based solutions are used to solve the city's wicked economic, social and environmental challenges (Greco & Cresta, 2015). Without proper understanding and management of existing wicked problems, the negative effects of smart technologies can surpass the positive ones. In order to identify and avoid such potential challenges related to the rapid smart city development, is necessary to operate it in an innovative way with a creative user-centric approach to problem-solving (Greco & Cresta, 2015). According to this interpretation of the smart city, identification and management of wicked and complex problems requires a creative and innovative approach starting from a human perspective, developing solutions that are not only technically feasible, but also economically viable and desirable for the target group (Plattner, Meinel, & Leifer, 2015). Design thinking method is an approach known for combining mindset, process and methodology to understand and deal with the wicked problems within their own context (Greco & Cresta, 2015; Mootee, 2013; Pavie & Carthy, 2014; Pavie, Carthy, & Sciences, 2015; Plattner et al., 2015; Thoring & Müller, 2011). While design thinking is a known method in the area of industrial innovation, it is less common for tackling wicked problems in urban planning practice. Therefore, our goal with this article is to understand how the creative mechanisms of design thinking work in the junction between smart city and urban planning, and how the approach might be adapted to different contexts and cases. Through this study of particular cases we also aim to increase the general understanding of design thinking as a mindset, process and method in (smart) city planning processes.

In the following, we describe how we applied design thinking in a participatory manner in three different situations related to urban planning and smart city challenges. We further divide the generated knowledge to two main categories of 'explorative' and 'exploitative', adopted from the open innovation theory in the smart city literature, which adds weight to the capacity of smart cities in balancing these two modes of innovation, called 'ambidextreousity' (B. F. Nielsen et al., 2018; Raisch & Birkinshaw, 2008). Explorative innovation implies innovation that is developed through lateral thinking and creative problem solving, while exploitative innovation means innovation built on existing knowledge and practices.

With this background, our research question is:

How can we apply design thinking to generate knowledge ('explorative' or 'exploitative') relevant for solving wicked problems in urban planning for smart cities?

3 DESIGN THINKING

Design thinking is considered as a mindset typically implying empathic, creative and innovative processes and methods for reducing bias in decision-making and reach better solutions balancing multiple needs and interests. Design thinking can contribute to improve our (urban) societies and build upon common values (Liedtka, 2015; Martin & Martin, 2009). Processes following a design thinking mindset are iterative, including different design steps that move from generating insights about end users through empathic approaches, to idea generation and testing, further evaluation and implementation. Moreover, design thinking involves the use of visual approaches for processing and communicating complex issues; producing visual diagrams, artifacts and prototypes helps multidisciplinary teams work together.

Design thinking emerges from the idea that one can understand and analyze how designers (industrial designers, architects or urban planners) think in action while designing. Design thinking has become a tool to tackle ill-defined or unrevealed problems (wicked problems) because it reframes these types of problems in human-centric ways, allowing the designer to focus on issues most important for users andcustomers. Innovators applying design thinking yet often refuse to systematize their methods to avoid limiting their innovation capacity and there is no specific given sequence of methods. Instead innovators or designers will go through messy (divergent) phases of lateral thinking and structured phases intuitively, finding new

connections, giving it potential to be the 'competitive advantage' of innovative firms (Martin & Martin, 2009).

Indeed, innovation and design research has shown that following methods or processes strictly does not necessarily lead to a greater ability to 'leap' between problem and solutions. Accordingly, design thinking often asks "what if?"–questions to imagine future scenarios freely rather than accepting the way things are done now, emphasizing the creative and intuitive ways of solving problems.

4 METHODOLOGY

This paper aims to develop in-depth descriptive-analytical perspectives contributing to explain how and why design thinking should be applied in planning of smart cities. This paper not only discusses 'how' outcomes were produced in the case studies at hand, but also tries to understand 'why', i.e. more than just finding out what those outcomes were. Yin (2009, p.18) believes that the case study "has a distinct advantage when a 'how' or 'why' question is being asked about a set of events within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". Accordingly, the best research strategy is the case study that provides the opportunity to obtain an in-depth investigation of a given phenomenon, within its context, by using a variety of workshops and data sources (Yin, 2012). In this paper, the case studies are descriptive, while the analysis is focused on the role and appropriateness of design thinking in these cases. Our study builds upon experiences from five workshops on three different themes, organized as parts of research projects involving researchers from the Norwegian University of Science and Technology (NTNU) and SINTEF. Each workshop focused on a distinct aspect of smart city: 'Energy', 'Participation' and 'Mobility', making sense of key challenges facing the cites when transitioning from traditional urban planning towards 'smart' urban planning. In each case, we arranged various workshops and applied the design thinking as the analytical, theoretical and methodological framework to test the creative mechanisms of design thinking to investigate how they might be improved. Because there is no specific given sequence of methods, each case represents varied steps and processes of the most widely known design cycle, namely 1) empathy/insight, (2) define problem, (3) idea generation, (4) prototyping, (5) testing (see fig. 1).

5 CASES

The three cases described below concern different wicked problems and has been selected from our research activity within the last two years 2017/2018. The economic limits and the research design of each project directly impacted the amount of time and preparation available for each workshop, explaining the varying length and how deeply anchored the research process could be. However, all workshop was based on the design thinking mindset and process, and we used storytelling in all five workshops as a starting point to gather participants insight.

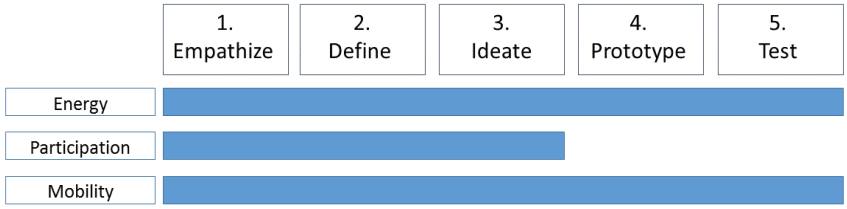

Figure 1: Different stages of a design process reached through the workshops in each case

As the diagram in figure 1 shows, although the workshops were facilitated through different methods, the design cycle of the five steps was similar. Although the workshops were facilitated through different methods, the purpose of the methods were following the design cycle in figure 1. The energy workshop lasted through two days and included both prototyping phase and a test of this prototype. Case 2, the participation workshop lasted only two hours, and reached the ideation stage, barely beginning to prototype new solutions. Case 3, the mobility workshop, lasted one day and reached the ideation stage.

5.1 Case 1: Smart Energy

Bergen and Oslo wanted to develop better tools for integrating 'smart energy' into their municipal planning processes. The methods and process were chosen as results of preliminary interviews with each relevant

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

stakeholder and analysis of key challenges and need for planning tool. One workshop was held in Oslo and another in Bergen, including urban planners, utility companies, architects, researchers and the climate departments of each city (B. F. Nielsen et al.). The two workshops in case 1 included a storytelling session, in which the experiences of planning the two pilot projects Furuset in Oslo and Zero Village Bergen was used and shared. Then, participants were divided into different groups. Their task was to divide the stories into three categories of 'goals, strategies and challenges' (Jonassen, Hernandez-Serrano, & Development, 2002; Swanson & Gordon, 2012). Then, they had to select one of the goals that they would like to achieve for the planning of future Smart Energy Communities. Finally, each group placed the goal on the top of a ladder and then defined which steps were needed to get there (a method known as back casting). In this first workshop, illustrated in figure 2 below, participants designed four different proposals, indicating how energy could be better integrated into municipal planning. Their discussions were recorded and transcribed, along with the outputs of their task. Two back casting ladders were produced, and the researchers combined these into one step-by-step approach including the challenges and strategies suggested by the participants in each workshop. The resulting process was named the 'Smart Energy Community Planning Wheel' (B. F. Nielsen et al.).

In a second workshop with both municipalities and international reference group represented, the outcome, the conceptual planning process, was tested through a simulation called an analogue decision making theatre (Walsh et al., 2013) inspired by Lego Serious Play (Schulz, Geithner, Woelfel, Krzywinski, & Management, 2015). We used Lego building blocks to create scenarios and asked the urban planners from both municipalities to recreate the planning process of the two neighborhoods, applying the new planning wheel together with researchers (B. Nielsen, Lappegard Hauge, Sørnes, Taxt Walnum, & Uusinoka, 2018).

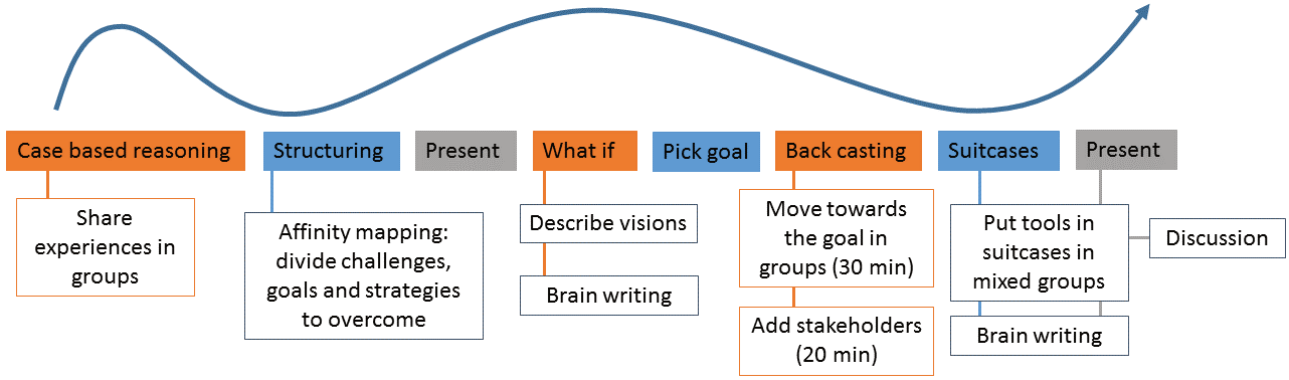

Figure 2: Outline of first workshop with Bergen and Oslo municipalities and private stakeholders on goals and strategies for smart urban energy planning.

5.2 Case 2: Smart Participation

The second case, in which design thinking was applied, was to look at how citizen participation can be done with the improved technologies of smart cities. The problem formulation originated from studies on challenges to develop sustainable neighbourhoods within the Zero Emission Neighbourhoods research center (FME ZEN) and Planning Instruments for Smart Energy Communities (PI-SEC) (Baer, Andresen, 2018). Until now, nine pilot projects in eight Norwegian municipalities have tested and implemented solutions to lower the carbon emission while planning, developing and operating the neighbourhood. Previous studies of these cities have shown urban planning fails to implement ideas emerging from citizen participation activities (Nielsen, Baer, Lindkvist, & Change, 2018). A workshop applying design thinking to the issue of smart participation was arranged at the ISOCARP conference 2018 in one of the pilot cities, Bodø city. Bodø has also decided to become a smart city, inviting world leading technology developers to develop smart urban fabric and citizen laboratories. This was a chance to investigate how citizen participation could be 'reframed' in smart city projects in Bodø, together with urban planning experts with a local, national and international background.

The workshop was set up similarly to Case 1, starting with storytelling, identification of goals, challenges and strategies and ending with an early prototyping process. The main difference was that this workshop had a timespan of only 90 minutes, while the workshops in case 1 were full day workshops. Therefore, three stories of challenges in citizen participation were prepared by the researchers based on the previous analysis,

saving time and linking the stories to previous studies. The participants were asked to use these stories as inspiration for prototyping new solutions for what citizen participation could look like in a smarter future. Participants were local, national or international based and came from public, private and research sector. The workshop was facilitated at the Bodø Citylab, a physical meeting space for stakeholder engagement at the public library in Bodø.

5.3 Case 3: Smart mobility

The third and last case was conducted as a part of a collaboration between the Norwegian Directorate of Public Roads [Vegdirektoratet] and the Smart Sustainable Cities research group (SSC) at NTNU to figure out the regulatory pitfalls of mobility in future smart cities. Mobility experts from private and public sector and academia participated in a design-thinking workshop in Trondheim, in order to identify the necessary regulatory steps to avoid the most common pitfalls of mobility in smart cities.

Participants included the Directorate of Public Roads and private companies supplying mobility services, the Norwegian Cyclists' Association, urban planners, and urban planning researchers, as well as other interested land use and mobility experts. Taking as a starting point the task to identify pitfalls, storytelling was combined with 'worst case scenario approach' for problem statement and idea generation. The worst-case scenario approach is well known from design thinking and user experience design, and risk management, as a method in which the participants use lateral thinking to come up with new connections and solutions to problems. First, the method includes developing a step-by-step worst case situation, and then moves towards solutions again (Carrol, 1999; Gollier, Treich, & Uncertainty, 2003). The double diamond process is a model of the insight, idea generation, structuring, prototyping and testing process common for design thinking. In this case, the worst and best scenario were the 'conceptual prototypes' while stories were 'insights' to empathize the participants (fig. 1).

6 FINDINGS

In general, participants gave positive feedback about the processes and the possibility to discuss cross-disciplinary issues. One urban planner expressed, the joy of discussing how to solve relevant challenges in a future oriented way, saying that

'I think we should use design thinking in our work!'

Urban Planner, Bergen

The data collection of drawings, models, voice, video and notes taken to describe discussion, provided specific insights into solutions and challenges and the ability for different sectors to learn about each others practice based challenges in integrated urban planning. Moreover, the data gathered provided research access to multiple levels of challenges and issues relevant for working with the wicked problems of municipal planning meeting smart city challenges. Bringing researchers into the participatory process also provided the ability to guide the testing of certain theories and knowledge for each topic.

6.1 What type of knowledge can be extracted through design thinking processes in smart cities?

The typical design thinking process as tested, generated different categories of knowledge, in which the facilitation, preparation, set-up, tools, sequence of tools, type and number of participants and analysis all play a role. Table 1 summarizes the output and the most important characteristics of each workshop. In each workshop, the researchers were also facilitators, observers and participants. It is important to emphasize that output and knowledge is not always equivalent.

6.2 Knowledge for open innovation in smart cities

The types of knowledge output described in table one can further be divided into three different categories, exploitative, exploratory, and 'ambidextreous', for the purpose of being relevant to design and open innovation theory: First, the exploitatory knowledge, developing insights into what the participants already know, and second the exploratory, "new" knowledge where new scenarios and ideas are generated through the lateral-thinking methods applied. Third, there is knowledge where the exploratory knowledge is combined with the knowledge presented by each participant based on their existing knowledge.

Exploitative (existing) knowledge can be divided into:

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

(1) Experiences and stories. Beginning each workshop with storytelling provided us with access to each stakeholder's perspective. The storytelling did not stop as the task was over, instead participants were inspired by this task to bring up own professional and personal stories throughout the workshop.

Cases	Focus/ wicked problem	Aim/ questions	Design thinking processes, techniques/ methods	Output	Participants	Any specific feature
Case 1: *Smart Energy*	New planning instruments balancing objectives of utility companies, municipalities, climate departments, private developers and citizens.	How can smart energy be better integrated into municipal planning?	1. Story-telling about the projects (selected by participant) A)Testing a model B) Storytelling C) Case Based reasoning: Identification of goals, strategies and challenges 2. Back-casting 3. 'What if' 4. 'Suitcases' (placing responsibilities and tools in different 'suitcases') 5. Testing with Lego in analogue decision making theatre	The Smart Energy Community Planning Wheel', a process of assessments, incentives and evaluation of smart and integrated energy planning. Identification of challenges in collaboration, drivers, roles and power relations, incentives to reach more integrated forms of energy planning.	Urban planners, utility companies, architects and researchers in the PI-SEC project	Background desk-research and interviews were conducted and analyzed to understand the issue to be studied.
Case 2: *Smart Parti-cipation*	New participatory approaches: pilots projects fail to operationalize insights from citizen participation	How could citizen participation be 'reframed' in smart city projects?	1. Storytelling (Three stories about real cases prepared by researchers) 2. Definition of challenge 3. Development of strategies to cope with challenges 4. Prototyping solutions with drawing	Conceptual prototypes illustrating the need and goals for motivating and real participation. Ideas of motivation for participation, level of participation and aim of participation. Identification of different understandings amongst stakeholders about the difference between participation and involvement.	Local, national or international based and came from public, private and research sector.	The physical setting for the workshop was city-lab, a physical meeting place for stakeholder engagement.
Case 3: *Smart Mobility*	A framework for understanding how to regulate to avoid pitfalls of mobility in smart cities.	To identify the necessary regulatory steps to ensure that the mobility situation in Norwegian cities reach the objectives citizens and authorities want, facing smart city challenges from existing global cases.	1.Storytelling (participants and researchers from real cases around the world) 2. Build a 'regulation staircase' from today's situation and try to make the smart city as terrible as possible (Worst case scenarios) 3. Back casting, using regulatory framework to move from worst case scenario to best case.	A value-based framework centering on trust, explaining how regulation must protect certain values in order to keep trust in our mobility system, and what the objectives of this value framework is.	Directorate of public roads, private companies supplying mobility services, the Norwegian Cyclists' Association, urban planners, and urban planning researchers and land use and mobility experts.	The task was suggested by the Directorate of Public Roads and not deduced from research/by the researchers. The origin might have directed the output and makes it more difficult to know if the problem is 'wicked'.

Table 1: A breakdown of outcomes and applied methods from each design thinking process in the three cases

(2) Existing strategies. As stories were analyzed by the participants in a case based reasoning approach, they had to explain which strategies were relevant for solving the challenge in the presented story. A long list of strategies were produced. In the Energy workshops, strategies for integrating energy into urban planning ranged from incentives for public private partnerships, to scenario building tools for urban planners.

(3) Individual stakeholder goals, the process also included identification of each stakeholder's goals, and goals ranged from company specific goals such as 'all houses attached to the district heating system' or 'making the city walkable'.

(4) Challenges and limitations were described during the discussion, during the worst-case scenario workshop and the case based reasoning process. In the Mobility workshop, for example, challenges ranged from open data challenges to the emergence of self-driving vehicles and lack of incentives for land protection.

Exploratory (new) knowledge:

(5) 'What if' scenarios. 'What if' methodology (Kankainen, Vaajakallio, Kantola, Mattelmäki, & Technology, 2012) where used to develop new ideas and goals for further development, and were concluded in future scenarios. This method has the effect that it inspires the participants to explore and come up with new ideas that may be relevant for future scenarios.

(6) Worst case, lateral-thinking scenarios. The worst-case scenarios developed represent new and co-produced knowledge where participants had to connect different stories and developments based on stories that we had collected from around the planet about smart city developments. The worst-case scenarios included the participants' worst fears, and gave insights into which values the participants wanted to protect.

(7) New concepts. New concepts were developed, often emerging from the 'what-if' exercises of from the conversations following storytelling. In the Participation workshop, for example, a basketball court was presented as an idea, as a metaphor for how the municipalities should have 'basketball nets' to receive ideas from citizens.

Ambidextrous knowledge - 'New' knowledge combined with previous experience can be divided into:

(8) Specific contributions and responsibilities related to the topic were identified through the 'suitcase' method where participants were asked to place new and existing tools for smart city development into new suitcases of responsibility.

(9) New strategies and goals were developed based on the storytelling and scenario building. For example, the mobility workshop produced value orientation for avoiding the worst-case smart city scenarios.

(10) New 'ambidextrous' concepts. Concepts are new ideas of how a challenge can be overcome, and can take form as a written, spoken or visualized concept during the workshop. In all the three workshops, we asked participants to describe future scenarios, and these were documented by transcription, recording, photo and/or video.

(a) Common stakeholder goals as decided during scenario development can be seen as new concepts, or new stories.

(b) Visualized concepts such as a new planning process or a staircase model for regulating smart mobility.

(c) New stories or scenarios.

As the recordings and documentation of the co-produced ideas were brought back to our offices, a deeper analysis and categorization of the data gathered (discussions, storytelling, concepts) could be done. We could match the identified challenges with desk research of the projects, international lessons and best practices. This led to the identification of a deeper level of understanding of ambidextreous knowledge.

(11) Underlying stakeholder agendas: From a deeper analysis of the recorded discussions, combined with previous interviews and research data, an analysis of each stakeholder agenda could be made and mapped in relation to other stakeholder's agendas. This gives an idea of how the stakeholder contributes in relation to overarching goals such as sustainability or societal well-being.

(12) Core values and relevance to international cases: By combining the findings of the mobility workshop with international case reviews, we developed a set of core values and their role in protecting against certain smart city pit-falls. This resulted in a trust-based framework for triple bottom line sustainability in mobility regulation. This shows how design thinking workshop processes can provide empirical data for developing frameworks for further theoretical or practical application.

(13) Wicked problems: Some problems remain unresolved by the participants, and instead generate critical discussion and engagement, conflicts or new questions. Challenges that are harder to accomplish generate more discussion, and this can be noticed when going through the recordings from the workshops. Some questions could simply not be answered by one strategy. For example, during the mobility workshop, stakeholders discussed whether a new smart mobility scenario means that there will be more international stakeholders pushing for increased private mobility, and if so, what will be the incentives for walking? In the Energy workshop, similar issues came up relating to the trend of incentivizing private sector for reaching strategic policies in the municipality. How do we incentivize the citizens' needs? This is identified as a 'wicked problem' by observing that these issues create debate and participants keep returning to discuss these issues of cross-sectoral importance.

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

7 DISCUSSION

We introduced the need for design thinking as it has been shown how cities fail to balance explorative and exploitative innovation and to use existing knowledge well in innovative neighborhood pilots (Lindkvist et al., 2018; B. F. Nielsen et al., 2018). If we place the findings into the framework of exploitative, explorative and ambidextrous knowledge management (Filippini, Güttel, & Nosella, 2012), we can see that these methods work in combination, bringing the participants from exploitative learning, through explorative and towards a situation where they build upon existing knowledge and experience to build new knowledge. Also, participants move between the exploitative, returning to experience and profession, while solving the explorative tasks. While the purely explorative methods have the function to generate lateral, 'intuitive' thinking, the co-produced knowledge takes an ambidextrous form, meaning that the participants build on existing knowledge and combine it with exploration of new connections. By co-produced knowledge, we mean the direct output from the workshops that can directly be transcribed or documented visually because of the design thinking process. This leads to the ambidextrousity needed for open innovation in smart cities.

Exploitative knowledge (co-produced)	Explorative knowledge (co-produced)		Ambidextrous knowledge (co-produced)		Ambidextrous knowledge (research analysis)
Empathize	Define	Ideate	Prototype	Test	After workshop

Table 2: Types of knowledge categorized in relation to the design cycle's steps and Ambidextrous Knowledge Management (AKM)

This categorization shows that design-thinking process can be appropriate for achieving ambidexterity in stakeholder collaborations. The process in which the participants build upon previous experiences and knowledge in a topic to build new concepts and strategies indicates that design thinking, when applied as a research method, can be a transformational approach. The ability to translate and innovate from large amounts of various data and lead participatory processes will be a necessity. The role of facilitation and transformation also puts in question the role of the facilitator. The framing of the workshop, which participants are included and how these networks and processes are facilitated will influence the result.

From our experience, it is important to put relevant stakeholders of different sectors and opposing views in the same workshop, to truly 'understand the rules' of a game which the goal of design and design thinking is. If facilitated well and managed consciously through large stakeholder-led innovation projectsdesign thinking can be a catalyst, yet this will depend upon, that the the owner(s) of the problem are involved in the workshop, the set-up and facilitation of the workshop, and whether the owner of the problem has the role and position to implement the changes explored. In the mobility workshop, the identified value framework will be utilized by the Directorate of Public Roads and detailed further by students and experts. In the Energy workshop, a recommendation for new planning instruments will be shared with international and national stakeholders. From the Participation workshop, we will utilize the findings for further research purposes. As a mind-set, design thinking offers unique opportunities to improve collaboration in the quadruple helix of citizens, businesses, city administration and research for plans realising the aforementioned public objectives.

The outcomes of the workshops show that the potential of design thinking for reconciliation of conflicting feelings and interests was clearly acknowledged, albeit time-consuming and challenging to satisfy all actors. However, the participants indicated a host of preconditions for such a process in order to be successful. At first, information has to be shared at an early stage in the process but bridging discrepancies in level of knowledge can also help, as was done in the Energy workshop by having researchers explaining how to use the tool presented. In addition, different abilities to influence the proposed actions should be recognized beforehand, as real participation is more than providing information. The findings also illustrate a couple of strategic elements which should be part of any design thinking-based co-design trajectory, such as accessibility to high-quality information for participants, and this adds to the need for research enhanced knowledge to be introduced as a more deliberate step, not only after the workshop.

It is worth discussing how the wide and creative approach for linking different topics through such a transformative approach compares to other methods such as comparative studies or user surveys. The answer may be that while design thinking is good for designing concepts and creating value-based visions for problem-solving, other, more specific approaches are needed to detail and direct specific steps and final

designs. Design thinking has shown to be appropriate to integrate and make meeting points where there is no clear solution (or not even a clearly identified problem!) while for more structured and well-defined problems it would be unnecessary.

8 CONCLUSION

As the transition into a new city paradigm of smart cities, we will need to learn and innovate in an ambidextrous way, building on what we know but exploring how the future will challenge us. Knowledge management theory emphasize the importance of knowing how to apply ambidextrous learning paths in times of change (Filippini et al., 2012). The design thinking process allows to deal with multiple concerns and balance different objectives, moves from exploitatory, through exploratory and towards ambidexterity, in which there is a resulting prototype illustrating how new and existing knowledge can help solve wicked problems.

Design thinking provides an approach for bringing together all angles of a problem, multiple stakeholders, while keeping the end-user at the center of attention. Design thinking can reduce bias, and our processes showed that by taking into account multiple experiences through storytelling, breaking them down and using them for new goal formulation, made results from the level of technical detail, but also deeper discussion on 'why' (or why not!) we shouldto integrate technologies and utilities into our planning and design.

Many of the findings are co-produced, yet we also show that 'wicked problems' and complex relationships can be identified, studied and made sense of by further analyzing the output. As large parts of the results of the workshop cases were value oriented issues, perhaps one of the important roles of design thinking can be to facilitate the creation of value frameworks and visions for how the smart cities should be defined. Should researchers be observers of the process of smart city design and implementation, or should we as designers of change, not 'miss significant opportunities to change the rules of the game"(Brown & Katz, 2011). Here comes also design agency and our own role in (Margolin & Margolin, 2002). As in co-design, the facilitator has power over the outcome and therefore we must be clear about our own role in the facilitation, but also in the analysis.

We suggest that design thinking should be used at a larger scale to develop more flexible approaches to urban planning, regulation and policy and space making in smart city futures. This way, researchers, citizens, industry and municipalities can build knowledge and innovation frameworks that contribute to continuous ambidextrous innovation, and apply this way of thinking as an approach of identifying the key areas and core values for open innovation in smart cities. Ambidextrous learning might in fact distinguish the smart city from the less smart one.

9 ACKNOWLEDGEMENTS

We acknowledge the support from the Research Council of Norway and several partners through the research project Planning Instruments for Smart Energy Communities (PI-SEC), the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN), the Directorate of Public Roads [Vegdirektoratet] and all participants in our studies.

10 REFERENCES

BAER, D., & Andresen, I. ZEN pilot projects: Mapping of the pilot projects within the Research Centre on Zero Emission Neighbourhoods in Smart Cities. ZEN Report 10. 2018.

BROWN, T., & Katz, B. J. J. o. p. i. m. Change by design. In: xxx 28(3), 381-383. 2011

CARROL, J. M. Five reasons for scenario-based design. Paper presented at the Systems Sciences, 1999. HICSS-32. Proceedings of the 32nd Annual Hawaii International Conference on.

CHURCHMAN, C. West. Guest editorial: Wicked problems. In: xxx B141-B142. 1967.

FILIPPINI, R., Güttel, W. H., & Nosella, A. J. J. o. B. R. Ambidexterity and the evolution of knowledge management initiatives. In: xxx 65(3), 317-324. 2012.

GOLLIER, C., Treich, N. J. J. o. R., & Uncertainty. Decision-making under scientific uncertainty: the economics of the precautionary principle. In: xxx 27(1), 77-103. 2003.

GOODSPEED, R. J. C. J. o. R., Economy, & Society. Smart cities: moving beyond urban cybernetics to tackle wicked problems. In: xxx 8(1), 79-92. 2014.

GRECO I., & Cresta, A. A smart planning for smart city: the concept of smart city as an opportunity to re-think the planning models of the contemporary city. Paper presented at the International Conference on Computational Science and Its Applications. 2015.

HARTMANN, T. J. P. T. Wicked problems and clumsy solutions: Planning as expectation management. In: xxx11(3), 242-256. 2012.

JONASSEN, D. H., Hernandez-Serrano, J. J. E. T. R., & Development. Case-based reasoning and instructional design: Using stories to support problem solving. In: xxx 50(2), 65-77. 2002.
KANKAINEN, A., Vaajakallio, K., Kantola, V., Mattelmäki, T. J. B., & Technology, I. Storytelling Group–a co-design method for service design. In: xxx 31(3), 221-230. 2012.
LIEDDTKA, J. J. J. o. P. I. M. Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction. In: xxx 32(6), 925-938. 2015.
LINDKVIST, C., Juhasz-Nagy, E., Nielsen, B. F., Neumann, H.-M., Lobaccaro, G., Wyckmans, A. J. T. F., & Change, S. Intermediaries for knowledge transfer in integrated energy planning of urban districts. In: xxxx 2018.
MARGOLIN, V., & Margolin, S. J. D. i. A “social model” of design: Issues of practice and research. In: xxxx18(4), 24-30. 2002.
MARTIN, R., & Martin, R. L. The design of business: Why design thinking is the next competitive advantage. Harvard Business Press. 2009.
MOOTEE, I. Design thinking for strategic innovation: What they can't teach you at business or design school: John Wiley & Sons. 2013.
NAM, T., & Pardo, T. A. Smart city as urban innovation: Focusing on management, policy, and context. Paper presented at the Proceedings of the 5th international conference on theory and practice of electronic governance. 2011.
NIELSEN, B. F., Lappegard Hauge, Å., Sørnes, K., Taxt Walnum, H., & Uusinoka, T. Municipal practice and project planning, Toolkit testing. PI-SEC Report 1.3/2.3. Trondheim. 2018.
NIELSEN, B. F., Baer, D., Lindkvist, C. J. T. F., & Change, S. Identifying and supporting exploratory and exploitative models of innovation in municipal urban planning; key challenges from seven Norwegian energy ambitious neighborhood pilots. In: Technological Forecasting & Social Change (2018, in press).
NIELSEN, B. F., Juhasz-Nagy, E., Lindkvist, C., Wyckmans, A., Andresen, I., & Baer, D. Planning Instruments for Smart Energy Communities. PI-SEC Report Nr. XXXX. Trondheim. 2017.
PAVIE, X., & Carthy, D. J. A. a. S. Addressing the wicked problem of responsible innovation through design thinking. In: xxxx 2014.
PAVIE, X., Carthy, D. J. P.-S., & Sciences, B. Leveraging uncertainty: a practical approach to the integration of responsible innovation through design thinking. In: xxxx 213, 1040-1049. 2015.
PLATTNER, H., Meinel, C., & Leifer, L. Design thinking research: Making design thinking foundational: Springer. 2015.
RAISCH, S., & Birkinshaw, J. J. J. o. m. Organizational ambidexterity: Antecedents, outcomes, and moderators. In: 34(3), 375-409. 2008.
RITTEL, H. W., & Webber, M. M. J. P. Planning problems are wicked. In: xxx 4(155), e169. 1973.
SCHULZ, K. P., Geithner, S., Woelfel, C., Krzywinski, J. J. C., & Management, I. Toolkit-Based Modelling and Serious Play as Means to Foster Creativity in Innovation Processes. In: xxxx 24 (2), 323-340. 2015
SWANSON, R., & Gordon, A. S. J. A. T. o. I. I. S. Say anything: Using textual case-based reasoning to enable .open-domain interactive storytelling. In: xxxx 2(3), 16. 2012.
THORING, K., & Müller, R. M. Understanding the creative mechanisms of design thinking: an evolutionary approach. Paper presented at the Procedings of the Second Conference on Creativity and Innovation in Design. 2011.
WALSH, C. L., Glendinning, S., Dawson, R. J., England, K., Martin, M., Watkins, C. L., Parker, D. Collaborative platform to facilitate engineering decision-making. Paper presented at the Proceedings of the Institution of Civil Engineers-Engineering Sustainability. 2013.