Design Thinking for Sustainability in Smart City: Investigating Design Thinking Workshop Processes and Methods

Seoyoung Kim, Heejung Yim, Hyochang Kim, Hyunmin Kang

Stanford Center at the Incheon Global Campus (SCIGC), Stanford University

Abstract: Advanced technologies are revolutionizing the way people live and interact with everyday products, services, and experiences. Although significant progress has been made by integrating technologies in promoting task efficiency, high connectivity, and economic prosperity, environmental issues are frequently neglected. As consumer demands are growing and diversifying, organizations worldwide are keen to adopt design thinking as a catalyst for innovation. This study explores the significance of addressing environmental concerns and setting the sustainability agenda during the problem framing stage of design thinking. Through analyzing five design thinking workshops facilitated by SCIGC, the main objective is to explore the integration of sustainability approach within the problem and solution space of design thinking process. We expect this study will contribute to the discourse of design thinking, design for sustainability (D4S), and social innovation of smart cities.

Keywords: Design Thinking, Design for Sustainability, Human-Centered Design, Smart City

1 Introduction

Design has been implemented as an efficient approach, method, tool, or strategy to innovation in business (Ceschin and Gaziulusoy, 2016); however, as the consumer demands for sustainable living is increasing, global organizations are making efforts to implement sustainability into their external and internal systems. As a human-centered approach to solve complex problems, many organizations adopt design thinking as a creative methodology to find innovative and durable solutions by reframing the problem in users' perspectives. For the past two decades, design thinking evolved beyond a creative method or tool to solve problems. It has now become an innovative strategy, mindset, and value to diverse organizations pursuing radical transformation of their traditional norms and cultures. Design thinkers have the capacity to mitigate environmental and social degradations to a greater extent than economists, engineers, or governmental agencies (Garcia and Dacko, 2016). This is because they develop products and services that integrate empathy for the problem context into the design process. Previous studies have demonstrated that innovative ideas come from effective problem-framing and spending more time in the problem space is the key to generate novel solutions through various perspectives (Kim et al., 2023; Binder and Watkins, 2024).

As a preliminary research, theoretical review and case studies were conducted to portray various contexts of design thinking integration, relationship between sustainability and design thinking in smart city innovation projects. Based on the analysis of observing and recording the process of each workshop, this study synthesized qualitative data and insights from literature review, project cases, and workshops. Thus, proposing the future direction of sustainability design thinking workshop process model. This paper explores how design thinking process and methods are used to develop ideas concerning sustainability for smart city innovation. Through investigating the processes and methods of five design thinking workshops facilitated by Stanford Center at the Incheon Global Campus (SCIGC), the main purpose is to explore how sustainability approach can be implemented throughout the design thinking process. The focus lies in investigating the process and the use of methodologies. Final idea concepts of the workshops are not illustrated in this paper due to confidentiality of partnering organizations. The concept of design thinking in this study follows Herbert A. Simon's assertion about the logic of design, which illustrates that design is a way of thinking, concerning with how things ought to be (Simon, 1969). Thus, in this paper, workshop participants mentioned as 'designers' reflects a person who thinks and takes action to make things better than the current state, constantly seeking for improvements (Simon, 1969; Dunne and Martin, 2006). Overall, this research emphasizes the importance of incorporating sustainability aspects to design thinking process and methodologies for creating sustainable human-centered ideas – not only for organizations and institutions, but also for social innovation.

2 Design Thinking, Sustainability, and Smart City

Design thinking, a human-centered approach to problem finding and solving, has evolved into an innovation paradigm since it gained popularity through Stanford d.school's curriculum (Brown, 2008; Auernhammer and Roth, 2021; Garbuio and Lin, 2021). Accumulated research and practices that integrate design thinking has made consumer experience increasingly important as the core of design thinking lies in empathizing the user of a product (Augustin and Schabacker,

2019; Cooper, 2000). Various industry, academic, and governmental organizations worldwide use design thinking as a process, method, tool, and mindset from product-service innovation, transformation of their organizational cultures, to social and urban innovation (Elsbach and Stigliani, 2018; Schulders, 2022; AlAli et al., 2023). In this chapter, we conducted a literature review about the past, present, and future of design thinking, especially emphasizing the significance of adopting environmental concerns and sustainability agenda into enterprise and governmental projects.

2.1 The Impact of Design Thinking

As design thinking emerged as a response to the changing demands of a rapidly evolving world, where traditional methods to problem-solving became no longer sufficient, organizations are keen to apply design thinking as an innovation method for generating a competitive advantage (Dunne and Martin, 2006; Elsbach and Stigliani, 2018). However, challenge remains in the process of adopting design as an innovative strategy that involves rethinking business vision with the company's leadership and is often applied without a full understanding of its capabilities (Kernbach et al., 2022). Despite the challenge, 'designerly ways of knowing,' which is the way designers work, think, and tackle ill-defined problems, has triggered interests among scholars from management, engineering, and cognitive psychology - formulating and incorporating the concept of design thinking to their own areas of discipline (Buchanan, 1992; Lawson, 2005; Cross, 2006; Elsbach and Stigliani, 2018). Thus, the idea of practically and scholarly integrating design as a strategic source in diverse fields, especially in business and management, have spread worldwide since the early 2000s (Dunne and Martin, 2006; Carlgren et al., 2016a). The role of design thinking in value creation has been acknowledged not only in business sectors, but also in public projects to achieve social innovations regarding policies and services provided for people (Pirinen et al., 2022). The need for social and urban innovation extensively reached out to public sectors and non-profit organizations to create better places for living or even to elevate public services through participatory design (Brown and Wyatt, 2010; Design Council, 2015).

2.2 Enablers and Barriers of Design Thinking

The core of design thinking lies in deeply understanding end-users to find their unmet needs with a multidisciplinary perspective; therefore, this human-centered process is used as a creative tool for administration, governmental projects, and urban planning (Schulders, 2022; AlAli et al., 2023). Before discussing about the ways to successfully achieve smart city's sustainable innovation, we have investigated how scholars defined the enablers and barriers of implementing design thinking in business-related organizations.

Personality profile of a 'design thinker' listed by Tim Brown (2008) presents individuals who empathize people from multiple perspectives and work with integrative thinking that not only concerns analytical processes but also have abilities to view the problem holistically to create novel solutions. Moreover, optimism by challenging constraints, active collaboration with an interdisciplinary approach, and experimentalism towards an entirely new direction are the main capabilities of innovators. Kernbach et al. (2022) claim that success of the design thinking implementation for organizations depends on individual traits, mindsets, behavior, and education while resistance to change, risk avoidance, closed-thinking, and lack of competencies are the impediments. According to the in-depth interviews targeting twelve professionals from diverse fields, Kim's (2022) findings reflect the type of characteristics and elements that allow and prevent these innovators to generate novel ideas for their businesses, projects, or research. Five core aspects were suggested as enablers, which are open-mindedness, diverse and deeper experience, motivation and inspiration, easy start and low hurdle, ability to combine different things, and team relationship. The experts commonly mentioned that each component of enablers cannot act alone, which makes it essential in every respect when tackling a certain problem. On the other hand, selecting extreme ideas, lack of empathy, bias and miscommunication, external and internal negative aspects, and budget restrictions were indicated as barriers. Compromising due to diverse constraints, miscommunication, and conflict between the idea generators and decision-makers were the critical factors to prevent innovation because potential ideas can be initially misjudged – blocking the way of other creative ideas to be developed.

On an organizational level, sufficient resources, flexible and rewarding work structure and system, leadership support, risk-taking company culture, inspiring company climate, and innovation focused process were the factors that drive companies to challenge new ideas and promote entrepreneurial mindset of employees (Kernbach et al., 2022). Barriers to creativity and innovation also lie in the categories of resources, organizational structure and system, leadership, and innovation process (Carlgren et al., 2016b; Kernbach, 2022; Kim, 2022). Negative working atmosphere creates negative emotions such as fear and embarrassment, which eventually cause poor performance and distrust towards the company. As such, integrating design thinking in organizations is not an easy task. It holistically relies on the type of corporate culture, members' mindset, and both internal systems and physical infrastructure. Enablers and barriers analyzed above can be applied in any setting and organization that pursue innovation.

2.3 Design Thinking and Sustainability

Over the past two decades, globalization and the rise of global threats caused by climate change have prioritized environmental concerns in political agenda and emphasized the significance of innovation across both supply and demand

of the market (UNEP and TU Delft, 2009). According to the UNEP report (2009), efforts to reverse these environmental issues require disruptive transformation in every layer of the consumption and production levels – for achieving innovation in process, product, service, and system. Mitigating the inefficiencies during these production and consumption processes can eventually create and provide more sustainable products and services, as right material selection and integrating sustainability into design decisions allow companies to achieve higher value through sustainability. Organizations, consumers, and policy makers worldwide pursue a more sustainable design and processes for responding to rising environmental challenges. Design for Sustainability (D4S) is a concept involving eco-design and green production design and closely linked to sustainable product-service systems and systems innovation, which applies sustainability criteria for improving product design to overcome sustainability concerns (UNEP and TU Delft, 2006 & 2009; Dusch et al., 2011). For enterprises and governments to achieve D4S, Mckinsey & Company (2023) suggests three elements during the research and development phase: (1) reframing the way products use resources, change regulations, adopt circularity principles, and make use of customer insights; (2) keeping track of sustainability goals regarding emissions and cost impact of design decisions; (3) training the right mindsets and capabilities to integrate sustainability into every product and design decision. As such, the role of sustainability in product and service innovation goes beyond creating an eco-friendly outcome. D4S encourages organizations to meet consumers' needs on a systematic level – holistically considering social (people), economic (profit), and environmental (planet) aspects (UNEP and TU Delft, 2006).

While design is defined as a journey and a destination, design thinking is a "core way of starting the journey and arriving at the right destination at the right time (Mckinsey & Company, 2023)." Jennifer Kilian, Mckinsey partner, mentioned that design thinking is considered as a methodology to explore ideal future states to solve complex and wicked problems. It can become the biggest competitive advantage if customers' needs are satisfied. Although design thinking gained popularity as a driver of business innovation, sustainability is not addressed throughout the process unless the user intentionally incorporates it as a concept (Shapira et al., 2017). Previous research and projects connecting design thinking and sustainability are found in several advocates' studies, such as integrating design thinking within a principle-based sustainability framework for Strategic Sustainable Development (Shapira et al., 2017), creating a sustainable design toolkit that allows designers to incorporate sustainability concepts in a sustainable design strategy workshop (Dusch et al., 2011), applying design thinking for visioning the future of design-led sustainability innovation (Dewberry and Sherwin, 2002), and suggesting models for educating sustainable design thinking with SME professionals and undergraduate design students (de Eyto et al., 2008). Such studies are presented as evidence that the concept of sustainability and design thinking can be combined and correlate to each other for achieving innovation and responsible to the planet by minimizing harm.

2.4 Integrating Design Thinking and Sustainabillty into Smart City Projects

Technological advancement and rapid urbanization caused unprecedent challenges and benefits for people who live in smart cities. Governments and public authorities now face multifaceted problems due to growing diversity and complexity of environmental problems, socio-cultural issues, and citizen demands (AlAli et al., 2023). According to the World Commission on Environment and Development, the definition of sustainable development is referred as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (WCED, 1987)." Researchers of smart city argue that citizen-centered design approach is imperative to make humane, cooperative, and sociable cities (Schulders, 2022; AlAli et al., 2023). It is discussed that co-creation and systematical integration of all urban aspects are crucial to create a positive urban experience and innovation (Nielsen et al., 2019). As it is estimated that 66% of global population will be residing in cities by 2050 (UNEP, 2018), complexity of problems is expected to increase causing negative impact upon various aspects of the society. Toli and Murtagh (2020) defined sustainability "as the coexistence of social equity, conservation of the natural environment, economic vitality, and quality of life in the urban environment," which is one of the strategic goals of smart cities. The definition of smart city varies between countries; but in general, it is a resilient, inclusive, and collaboratively built city or platform that utilizes technology and data to improve the quality of life for all citizens by enhancing sustainability and fostering new industries (Gladstone et al., 2018; MOLIT, 2023). Performances of smart cities are evaluated based on six characteristics, which are environment, economy, mobility, people, living, and governance (Giffinger et al., 2007).

Following two case studies, 'The Bristol Approach' and 'Ecobici Public Bicycle Sharing System,' are examples of urban projects that reflect how smart cities pursue innovation by addressing the importance of sustainability at the same time focusing on the needs of citizens. The projects are summarized in turn.

The Bristol Approach was made to tackle issues in Bristol, England by the partnership of Knowle West Media Center (KWMC), Bristol City Council, and Ideas for Change. Under this approach, each project encourages interdisciplinary collaboration of citizens to co-design solutions, develop new skills, and make positive change toward a specific issue occurring in the city. As Bristol city wanted to explore new ways to collect air quality data, a citizen-driven air quality sensing project was held to hear the voices of local community. Cyclists, taxi drivers, and schoolchildren and their parents were the three main groups participated and most concerned with air pollution. The operating team found out that majority of people not only wanted to improve urban air quality, but also wanted to gain more information about how air pollution affects their health and where the cleanest air is in Bristol. Out of many different prototypes, light and portable air quality

sensor device was designed so that all citizens can easily carry it anywhere. This way, accurate and massive amount of data can be gathered without difficulty. Citizens who devoted in this project proactively changed their behaviors sustainably to collect and improve air quality. Consequently, challenging complex urban issue by citizen-driven approach implicitly built citizen trust, which is as important as coming up with a new solution to the problem (The Bristol Approach, 2023).

The initiatives of Ecobici, public bicycle systems in Mexico City, started as an alternative urban mobility model that can cover the important themes of the sustainability agenda: habitability and public space, air quality, climate change, soil conservation and mobility, etc. Hoping for a positive impact on reducing greenhouse gases and solving social, economic, and health crisis, this long-term project was intended to help reach the city's goals under Climate Action Plan. Initial phase was to change the negative socio-cultural perception towards riding bicycles and skepticism on the government's innovative projects, as citizens of Mexico City originally had stereotype that cycling was a poor man's mode of transportation and that it would cause more problems related to traffic congestion. However, through two years of extensive planning, studies about users and success cases, and experimentations, this project could increase citizen awareness about its advantages by operating a new public-private financial model with street advertising. As a result, implementing Ecobici system successfully provided a new form of accessibility and promoted a sustainable urban mobility scenario by gaining a deep understanding of citizens' needs before diving into the solution (Peralta, 2017; Ecobici, 2022).

Based on the premise that design thinking and creative approach can bring positive impact on human behaviors and innovation in smart cities, we have found enabling factors and implications that commonly run through the urban projects. These findings are based on comprehensive analysis of preliminary literature research and the two case studies summarized above.

Tackling an unknown problem is the key to innovation

To create a visionary product with high value, the problem should be unknown and solution undefined from the beginning (Garbuio and Lin, 2021). This type of innovative idea is associated with abductive reasoning, which is at the heart of design thinking. Abductive logic, "inference to the best explanation," shows that any new thought, idea, or concept cannot be validated beforehand; rather, the validation can only occur as future events unfold (Martin, 2009). According to this logic, most innovative ideas emerge from exploring observations and qualitative data of the socio-cultural dynamics in the problem-finding space where ambiguity is unavoidable; instead of relying on market research-based data that narrow down the possibilities of new ideas (Verganti, 2003; Garbuio and Lin, 2021). As both urban projects had to tackle wicked problems by taking sustainability goals and various stakeholders into account, they spent a considerable amount of time to discover and examine the problem space that allowed innovators to reframe problems based on users' latent needs.

Holistic views are made by multidisciplinary collaboration

Working in multidisciplinary teams brings many advantages during the entire process of design thinking, especially in the stages of needfinding, brainstorming, prototyping, and communication (Brown, 2008; Martin, 2009; Seidel and Fixson, 2013; Kim and Nah, 2019) The two urban projects involved people from diverse fields of study, occupation, age, gender, and lifestyle to generate inclusive solutions that can embrace as many people as possible. Holistic views are made through adopting different thoughts and opinions from others who have opposite or different experiences and perspectives. Although conflicts frequently occur in a multidisciplinary team due to miscommunication and opposed ideas, effective distribution of each team member's roles and clear understanding of the project goal creates higher chances on creating an unexpected and innovative outcome. To achieve sustainable innovation through multidisciplinary approach, it is crucial to accumulate teamwork experience and boost up the ability of holistic thinking.

Raising citizen awareness leads to building trust

The Bristol Approach showed the importance of citizen participation for the city's innovative project. Through the process of contemplating a particular problem to come up with a creative solution for all, many citizens acknowledged the severity of environmental issues they confront every day. During pilot testing session of using the device, one of the citizens mentioned that being more aware of the situation is sometimes more significant than solely collecting data. Awareness prompted people to make sustainable choices in their lives, such as getting rid of their cars to save the environment. Moreover, in case of Ecobici, changing conventional thoughts about cycling culture transformed human behaviors and ways of living to bring sustainable impact towards the society.

Embedding sustainability agenda as a core strategy

Organizations and governments are eager to set the sustainability agenda by making a commitment to consolidate environmental, social, economic, and ethical aspects for strategic decision-making (PwC, 2008). From reducing pollution, educating people about the consequences of climate change, promoting health and wellness of citizens, and respecting human rights, the two cases comprehensively covered these criteria of sustainability throughout the processes. As

sustainability agenda requires collaboration between all stakeholders, it became possible to foster the sustainability mindset of participants that ultimately leads to shaping both efficiency and reputation of the project.

3 Design Thinking Workshop Analysis: Process and Methods

This study analyzes five design thinking workshops conducted or co-conducted by SCIGC with a total of 126 participants. Table 1 provides a summary of the workshops held in the previous year. Each workshop was planned for different type of company, institution, or academic organization. Workshop themes were set differently as partnering organizations had different interests; however, the common factor was to find a theme for reframing problems and experiences occurring within smart city. Workshop participants were consisted of employees in case of partnering with a company, citizens for art & design foundation, and undergraduate students for university. As creativeness in design thinking emerges through the interplay of a multidisciplinary team and diversity, we encouraged our partnering organizations to recruit people whose professional backgrounds differ as much as possible. Thus, all five workshops included participants whose expertise are in design, engineering, management, information technology (IT), media art, science, applied physics, social sciences, economics, education, linguistics, etc. Four to six members with different backgrounds were grouped as a multidisciplinary team and facilitators were assigned to each team as an observer and advisor.

Table 1. Overview of design thinking workshops conducted or co-conducted by SCIGC

WS No.	Partnering Organization	Type, Number of Participants	Background of Participants	Workshop Theme	Days Spent
1	Software Company	Employees, 16	Engineering, management, IT	Creating a sustainable and innovative workplace for future organizations	1
2	Manufacturing Company	Employees, 23	Design, engineering, digital design, etc.	Generating a new concept for next generation mobility service	2
3	Art & Design Foundation	Citizens, 21	Engineering, industrial design, management, media art, applied physics, etc.	Constructing a motorboat for urban sailing experience	1
4	Energy Company	Employees, 21	Engineering, management, science, etc.	Innovating organizational culture for better communication and working experience (digital transformation)	1
5	University (Undergraduate)	Students, 39	Economics, management, engineering, education, linguistics, social sciences, physics, etc.	Rethinking autonomous car's future	1

Figure 1 shows the design thinking process and different methods used for workshops listed in Table 1. For all workshops, Stanford d.school's five phases of design thinking process (Stanford d.school, 2010) was implemented. During the planning of each workshop, facilitators from SCIGC and partnering organizations conducted several meetings to discuss the objectives and selection of methods for each phase. Each method was selected through the agreement of both parties and the rationale was made by choosing methods that were widely used and had to be easy to follow as most participants did not have enough experience with design thinking. Facilitators created new templates for methods such as 'data wall inspired by lotus blossom' and 'persona-empathy map' to match the flow of the workshops. The objectives were to focus on the fuzzy front-end of innovation and to introduce design thinking to participants who mostly were unfamiliar with this concept. Depending on the workshop theme, type of organization, and backgrounds of participants, we incorporated variation of design thinking methods for each stage of the process.
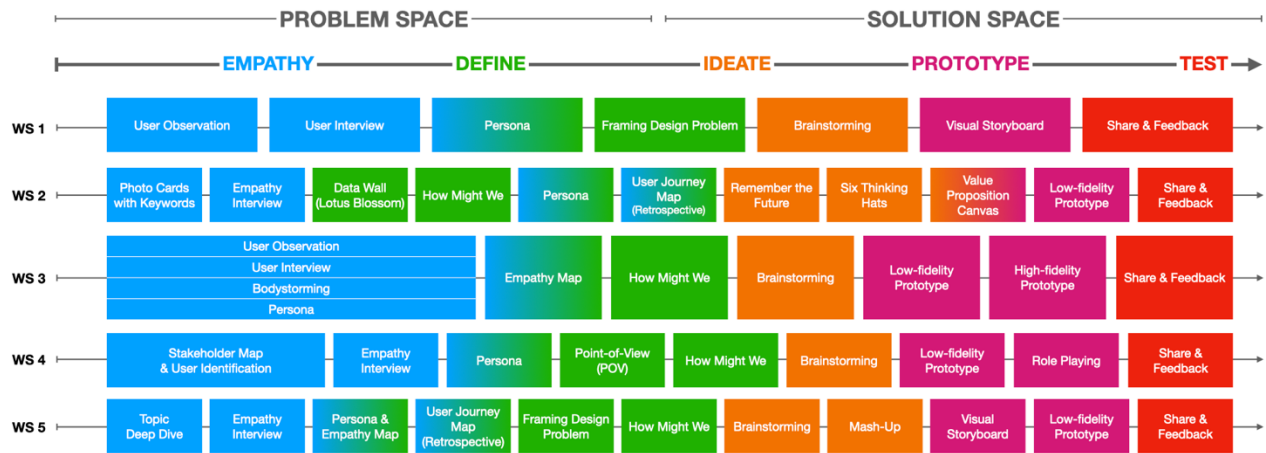
Figure 1. Process and Methods Used for Five Design Thinking Workshops

Following summary and insights captured during workshop processes are described based on observations from the facilitators and feedback received from workshop participants. From the planning stage, workshops 1 and 3 already had specific users in mind; thus, participants began with user observation by browsing through search engines, videos, literature, news, and trend reports. For workshop 3, teams rotated on going through four methods of empathy – user observation, user interview, bodystorming, persona – each team started with different methods. In the post-survey, we asked participants to evaluate each method of empathy regarding the effectiveness of its practiced orders. The results showed that the most effective way of empathizing was to start with user observation where the designers had to watch numerous photos and videos of people's behaviors and diverse situations about the topic. On the other hand, beginning with the user interview received the lowest score as most participants found it challenging due to uncertainty about which questions would elicit meaningful insights from the interviewees. Because participants from this workshop were citizens of smart city, who volunteered to learn about design thinking for a community project, they became the end user themselves and were actively engaged in the process.

As users were unidentified for workshops 2, 4, and 5, they began by diverging their thoughts about the topic. In these cases, empathy interviews were conducted to ask open-ended questions to collect qualitative data of what people think of a specific subject. Workshop 2 started with selecting keywords of social, economic, and technological trends that would later be used to draw out questions for empathy interview. For workshop 4, as the partnering enterprise had various clients as their users, they began by setting up stakeholder map to clearly identify users to focus on. In workshop 5, participants were actively involved while using persona-empathy map technique shown in Figure 2. By combining two methods, it allowed designers to easily immerse into the fictional character and set a clear overview of the user. Among the five workshops, workshops 3 and 4 dedicated more time in the empathy stage, with the main purpose of transforming participants' mindsets and training them about ways to deeply understand people.

For all workshops, persona and empathy map became the key for transitioning to the define stage with a clear understanding of their users. Application of retrospective user journey map helped participants place their persona in a specific topic-related scenario. Instead of jumping straight to the ideation stage after defining the problem, practicing this method allowed designers to imagine the context, needs, and opportunities surrounding the potential users. In comparison, implementing a prospective user journey map of the selected idea would effectively show the use case scenario. While planning for workshop 2, we have developed a template for data wall inspired by the 'lotus blossom' (invented by Yasuo Matsumura – originally a technique for idea brainstorming). Shown in Figure 2, this method starts from significant keywords that were selected in the previous stage and extends to the next step where designers can explore multiple challenges and insights – eventually leading up to defining several design problems from multiple perspectives.

Creative ideation techniques such as brainstorming, remember the future, six thinking hats (de Bono, 1999), and mash-up (IDEO U, 2015) were used to generate ideas aiming for quantity first, then refining for quality. Six thinking hats and mash-up techniques made designers think in diverse perspectives by shifting the mode of thinking. After a period of brainstorming, it is crucial to shift designers' thinking mode by employing alternative approaches to idea generation. Workshop 3 constructed a working prototype, while the other workshops progressed through a rough prototype stage utilizing visual storyboards to illustrate the implementation of their solutions. Due to time restriction, test stage was shortened and replaced with sharing other people's opinions about each team's final idea.
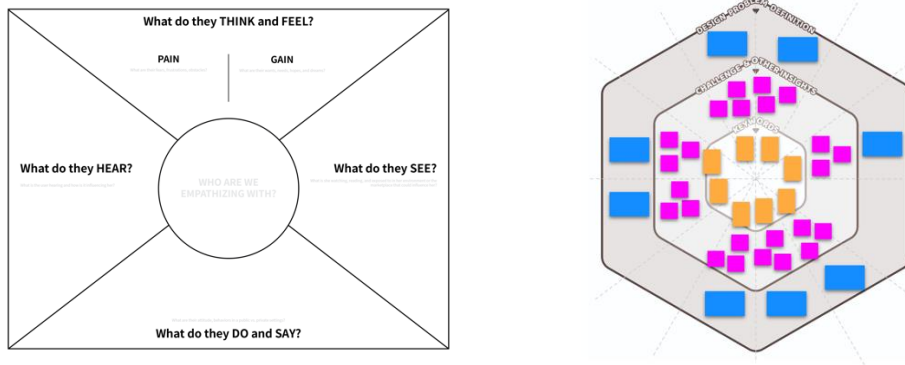
Figure 2. (Left) Persona-Empathy Map | (Right) Data Wall Inspired by 'Lotus Blossom'

4 Design Thinking for Sustainability in Smart City

Out of five workshops, only one of the workshop participants generated solutions considering sustainable impact. This is because the term sustainability was set as the theme and the purpose was to create a sustainable workplace for future organizations. None of the other workshop participants actively thought about the consequences of their creations (whether the outcome became a product, service, system, or an experience) in an environmental-friendly perspective. As Shapira et al. (2017) argued that design thinking does not integrate sustainability unless the user is willing to do so, including terminology related to sustainability as the main workshop theme is significant for raising designers' awareness throughout the entire process. When tackling a complex problem that occurs within a smart city, designers should generate solutions with a human-centered approach that implies sustainability factors regarding eco-friendly, energy efficient, and long-lasting outcomes. Design thinking workshops analyzed in this paper did not emphasize the need to apply sustainability factors or educate participants about sustainability in advance. The reason was to observe the natural flow of problem-solving processes and to evaluate sustainability awareness level of participants for finding phases where sustainability input is needed.

The proposed process of applying these factors is represented in Figure 3, which depicted the most effective methods and flow of operation based on the analysis of past workshops. Thus, we suggest implementation of sustainability input throughout the problem and solution space of design thinking process. Consistently providing information, questions, and tools regarding sustainablility to workshop participants will result in the development of ideas considering the impact upon sustainability, ultimately fostering a comprehensive understanding of the concept.
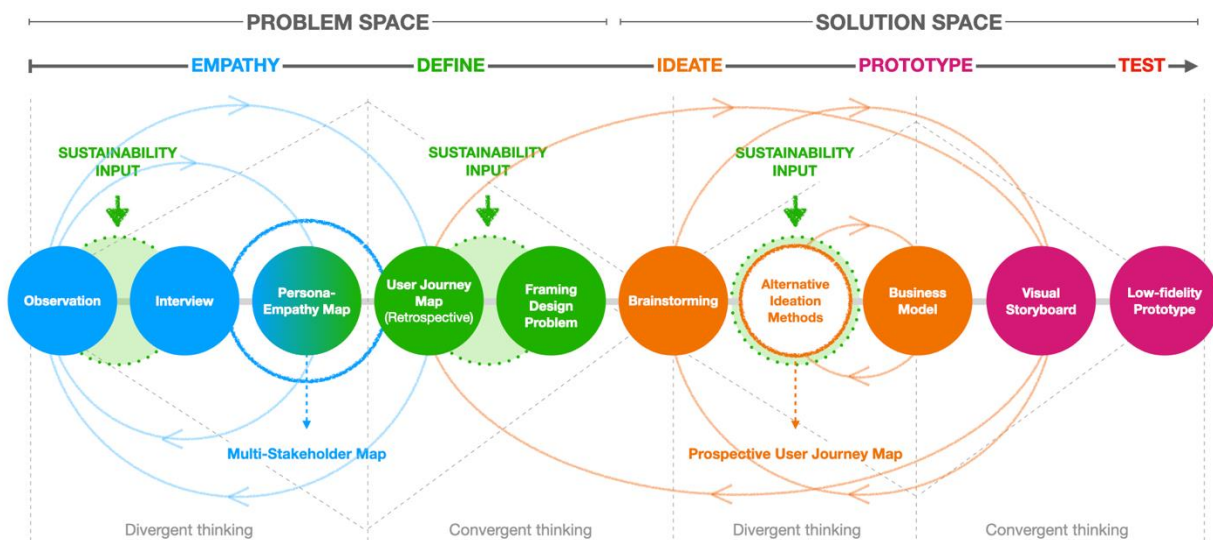

Figure 3. SCIGC's Sustainability Design Thinking Workshop Process Model

Setting sustainability agenda goals in the problem space

As the beginning phase of any process is critical to setting the scope and direction, fostering sustainability mindset is necessary from the early stage of empathy. Incorporating an additional step, where designers can substantially observe users with sustainability agenda in mind, would enable designers to discover new opportunities from users' behaviors, conversations, and touchpoints. After iterative observation of potential users, designers then would gain knowledge and ideas about how to compose interview questions while considering sustainability factors. The empathy interviews should include questions surrounding the environmental issues, social and economic challenges, and ethical factors, which will raise awareness and encompass a diverse range of problems. Considerations for setting sustainability agenda is listed below. The factors represent sustainability-oriented definitions of each dimension: social, environmental, and economic (UNEP and TU Delft, 2009; Toli and Murtagh, 2020). These were selected to be discussed in the problem space.

Factors to consider for establishing sustainability agenda of smart city while reframing the problem:

- Social (people): Ethical issues and equality, health and well-being, social engagement and interactions, safety concerns
- Environmental (planet): Climate change, all kinds of pollution, energy efficiency and consumption, infrastructure and utilities, use of materials and resources, sustainable urban development policies, biodiversity
- Economic (profit): Competitiveness, risk management and resilience, technology

While using persona-empathy map, it is important to consider various stakeholders as many smart city problems are multi-faceted. A holistic approach will help find users' unmet needs and desires. Our future practices will apply sustainability input in between constructing a retrospective user journey mapping and framing design problem statement. The structure of sustainability input is not finalized, but it will be designed as a guide or method that allows anyone to follow without difficulty.

Exploring solution space associated with production and operation processes

In our future design thinking practices, prospective user journey mapping will be incorporated after generating ideas through brainstorming. During the stage of refining and developing selected ideas, a prospective user journey map will act as a validation tool on reflecting implications of the solution upon users. Depending on the time allowance, employing alternative ideation methods by offering fresh new perspectives, can enhance the quality of generated ideas and broaden the pool of ideas. Sustainability input should be made at this stage of ideation where unexpected insights can emerge to create novel solutions or develop existing ideas by implementing sustainability considerations listed below.

Factors to consider for developing sustainability-oriented business ideas targeting smart city innovation:

- Social (people): Inclusive and accessibility, productivity, educational aspect, livability, improve quality of life
- Environmental (planet): Material selection, product lifecycle, use of resources by the product, product end-of-life recovery, preserving natural environment, emissions, optimize the utilization of available resources
- Economic (profit): Differentiator, customer proposition and value, digital intelligence, utilization of ICT, decrease costs

Within the solution space, iteration regarding idea refinement is necessary. Engaging potential end users into the idea generation, selection, evaluation, and testing process will enable designers to fully explore the solution space.

5 Implications, Limitations, and Future Work

This paper addresses the significance and value of incorporating sustainability perspectives and components to design thinking process. Particularly in responding to the challenges posed by wicked problems and complex systems of smart cities, the emphasis lies in the importance of educating designers and organizations on understanding the sustainable impact of their products or services against the environment. There are several limitations to this study. As the purpose was to focus on the process and methods of design thinking workshops, final ideas as solutions were not presented in this paper. However, by investigating the processes, we found opportunities where sustainability implementation should be made for developing sustainable ideas – concerning all aspects of people, planet, and profit. Furthermore, we have yet to outline how sustainability input will be shaped. As this research set the groundwork for devising a new flow, methodology, and toolkit for facilitating sustainability design thinking workshops, our prospective research will focus on constructing a framework that incorporates the insights depicted in this study.

References

AlAli, D., Manivannan, N., Xu, Y., 2023. A Framework for Effective Design Thinking based Smart Cities Projects in Qatar. Smart Cities 6, 531-562. https://doi.org/10.3390/smartcities6010025

Auernhammer, J., Roth, B., 2021. The Origin and Evolution of Stanford University's Design Thinking: From Product Design to Design Thinking in Innovation Management. Journal of Product Innovation Management 38, 623-644. https://doi.org/10.1111/jpim.12594

Augustin, L., Schabacker, M., 2019. Combining Scrum and Design Thinking for a Highly Iterative and User-Centric Hardware Development Project, Proceedings of the International Conference on Engineering Design, ICED '19. Published online by Cambridge University Press, pp. 2189-2198. https://doi.org/10.1017/dsi.2019.225

Buchanan, R., 1992. Wicked Problems in Design Thinking. Design Issues 8(2), 5-21.

Brown, T., 2008. Design Thinking. Harvard Business Review, June 2008. 84-92.

Brown, T., Wyatt, J., 2010. Design Thinking for Social Innovation. Stanford Social Innovation Review. 30-35.

Carlgren, L., Rauth, I., Elmquist, M., 2016a. Framing Design Thinking: The Concept in Idea and Enactment. Creativity and Innovation Management 25(1), 38-57. https://doi.org/10.1111/caim.12153

Carlgren, L., Elmquist, M., Rauth, I., 2016b. The Challenges of Using Design Thinking in Industry: Experiences from Five Large Firms. Creativity and Innovation Management 25(3), 344-362.

Ceschin, F., Gaziulusoy, I., 2016. Evolution of Design for Sustainability: From Product Design to Design for System Innovations and Transitions. Design Studies 47, 118-163. https://doi.org/10.1016/j.destud.2016.09.002

Cooper, R., 2000. Empathy and Technique in Design. The Design Journal 3(1), 1-2. https://doi.org/10.2752/146069200789393580

Cross, N., 1982. Designerly Ways of Knowing. Design Studies 3(4), 221-227.

de Bono, E., 1999. Six Thinking Hats. Back Bay Books. Boston, MA.

de Eyto, A., Mc Mahon, M., Hadfield, M., Hutchings, M., 2008. Strategies for Developing Sustainable Design Practice for Students and SME professionals. European Journal of Engineering Education 33(3), 331-342. https://doi.org/10.1080/03043790802088681

Design Council, 2015. The Design Economy: The Value of Design to the UK. Design Economy.

Dewberry, E., Sherwin, C., 2002. Visioning Sustainability through Design. Greener Management International 37, 125-138. http://www.jstor.org/stable/greemanainte.37.125

Dunne, D., Martin, R., 2006. Design Thinking and How it will Change Management Education: An Interview and Discussion. Academy of Management Learning and Education 5(4), 512-523. https://doi.org/10.5465/amle.2006.23473212

Dusch, B., Crilly, N., Moultrie, J., 2011. From Attitude to Action: The Development of the Cambridge Sustainable Design Tool Kit, Proceedings of the Cambridge Academic Design Management Conference, 7-8 September 2011. University of Cambridge.

Ecobici, 2022. Ecobici is Renewed and Expansion Stage Begins. https://ecobici.cdmx.gob.mx/en/ecobici-is-renewed-and-expansion-stage-begins/ (accessed 9.11.2023)

Elsbach, K.D., Stigliani, I., 2018. Design Thinking and Organizational Culture: A Review and Framework for Future Research. Journal of Management 44(6), 2274-2306. https://doi.org/10.1177/0149206317744252

Garbuio, M., Lin, N., 2021. Innovative Idea Generation in Problem Finding: Abductive Reasoning, Cognitive Impediments, and the Promise of Artificial Intelligence. Journal of Product Innovation Management 38, 701-725. https://doi.org/10.1111/jpim.12602

Garcia, R., Dacko, S., 2016. Design Thinking for Sustainability, in: Michael G. Luchs, K. Scott Swan, Abbie Griffin. (Eds.), Design Thinking: New Product Development Essentials from the PDMA. John Wiley & Sons Inc. pp. 381-400.

Giffinger, R., Fertner, C., Kramar, H., Kalasek, R., Pichler-Milanović, N., Meihers, E., 2007. Smart Cities: Ranking of European Medium-Sized Cities. The Centre of Regional Science (SRF), Vienna University of Technology.

Gladstone, N., Flatt, J., Fader, J., Hellstern, M., 2018. How to be Smart(er) in Mid-Sized Cities in Ontario. Evergreen and Code for Canada. https://futurecitiescanada.ca/portal/resources/how-to-be-smarter-in-mid-sized-cities-in-ontario/

Haaga-Helia, (n.d.). Lotus Blossom. https://www.haaga-helia.fi/en/ (accessed 25.7.2022)

IDEO U, 2015. Ideation Method: Mash-Up. https://www.ideou.com/pages/ideation-method-mash-up (accessed 20.8.2023)

Kernbach, S., Nabergoj, A.S., Liakhavets, A., Petukh, A., 2022. Design Thinking at a Glance: An Overview of Models Along with Enablers and Barriers of Bringing it to the Workplace and Life. 2022 26th International Conference Information Visualization. 2022 IEEE, pp. 227-233. https://doi.org/10.1109/IV56949.2022.00046

Kim, S., Nah, K., 2019. Investigating the Characteristics of Designers and Engineers for Multidisciplinary Collaboration: Focused on the Analysis of Design Thinking Workshop. Korea Institute of Design Research Society 4(2), 20-28.

Kim, S., 2022. Development of the Deep Ideation Model (DIM) in Design Thinking for Design-Driven Innovation: Focused on Improving the Quality of Ideas through Deep Thinking (Doctoral dissertation). Hongik University, Republic of Korea.

Kim, S., Kim, S., Koo, J., 2023. Needfinding Practice: Enhancing Students' Problem Framing Skills through Iterative Observation for Business Innovation, Proceedings of the International Conference on Engineering Design, ICED '23. Published online by Cambridge University Press, pp. 2775-2784. https://doi.org/10.1017/pds.2023.278

Lawson, B., 2005. How Designers Think: The Design Process Demystified (Fourth ed.). Architectural Press, Oxford, UK.

Martin, R., 2009. The Design of Business: Why Design Thinking is the Next Competitive Advantage. Harvard Business Review Press, Boston, MA.

Mckinsey & Company, 2023. What is Design Thinking? [online] Available at: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-design-thinking# (accessed 1.5.2024)

MOLIT (Ministry of Land, Infrastructure and Transport), 2023. Smart City Korea. https://smartcity.go.kr/en/

Nielsen, B.F., Baer, D., Gohari, S., Junker, E., 2019. The Potential of Design Thinking for Tackling the Wicked Problems of the Smart City, Proceedings of the 24th International Conference on Urban Planning, Regional Development and Information Society, pp. 761-770.

Papageorgiou, A., Wiberg, A., Persson, J., 2021. Introducing Multidisciplinary Design Optimization to Graduate Level Engineering Students, Proceedings of the International Conference on Engineering Design, ICED '21. Published online by Cambridge University Press, pp. 1917-1926. https://doi.org/10.1017 /pds.2021.453

Peralta, M.D., 2017. Lessons from Ecobici for the Implementation of Public Bicycle Systems in Mexico. Friedrich-Ebert-Stiftung, 1-10.

Pirinen, A., Savolainen, K., Hyysalo, S., Mattelmaki, T., 2022. Design Enters the City: Requisites and Points of Friction in Deepening Public Sector Design. International Journal of Design 16(3), 1-19. https://doi.org/10.57698/v16i3.01

PwC (PricewaterhouseCoopers), 2008. The Sustainability Agenda: Industry Perspectives.

Schulders, M., 2022. Co-creating Smart Cities: Design Thinking for 21st Century Urban Planning. European Research Studies Journal 25(2), 301-315. https://doi.org/10.35808/ersj/2922

Seidel, V.P., Fixson, S.K., 2013. Adopting Design Thinking in Novice Multidisciplinary Teams: The Application and Limits of Design Methods and Reflexive Practices. Journal of Product Innovation Management 30, 19-33. https://doi.org/10.1111/jpim.12061

Shapira, H., Ketchie, A., Nehe, M., 2017. The Integration of Design Thinking and Strategic Sustainable Development. Journal of Cleaner Production 140(1), 277-287. https://doi.org/10.1016/j.clepro.2015.10.092

Simon, H.A., 1969. The Sciences of the Artificial (Third ed.). MIT Press, Cambridge, MA.

Stanford d.school, 2010. Design Thinking Bootcamp Bootleg (The Bootcamp Bootleg). [online] Available at: https://dschool.stanford.edu/resources/the-bootcamp-bootleg (accessed 3.6.2022)

The Bristol Approach, (n.d.). Air Quality. https://www.bristolapproach.org/projects/air-quality/ (accessed 10.12.2023)

Toli, A.M., Murtagh, N., 2020. The Concept of Sustainability in Smart City Definitions. Frontiers in Built Environment 6(77), 1-10. https://doi.org/10.3389/fbuil.2020.00077

Tuomala, E.-K.S.E., Baxter, W.L., 2019. Design for Empathy: A Co-design Case Study with the Finnish Parliament, Proceedings of the International Conference on Engineering Design, ICED '19. Published online by Cambridge University Press, pp. 99-108. https://doi.org/10.1017/dsi.2019.13

United Nations Environment Programme (UNEP), Delft University of Technology (TU Delft), 2006. Design for Sustainability: A Practical Approach for Developing Economies

United Nations Environment Programme (UNEP), Delft University of Technology (TU Delft), 2009. Design for Sustainability: A Step-by-Step Approach

United Nations Environment Programme (UNEP), 2018. The Weight of Cities-Resource Requirements of Future Urbanization. Paris: International Resource Panel Secretariat.

Verganti, R., 2003. Design as Brokering of Languages: Innovation Strategies in Italian Firms. Design Management Journal 14(3), 34-42.

WCED, 1987. Our Common Future. Oxford University Press, Oxford, New York.

Wohler, J., Reinhardt, R., 2021. The Users' Perspective on How Creativity Techniques Help in the Idea Generation Process: A Repertory Grid Study. Creativity and Innovation Management 30, 144-163. https://doi.org/10.1111/caim.12424

Contact: S. Kim, Stanford Center at the Incheon Global Campus (SCIGC), Research Department, Research Scientist, 119 Songdo Munhwa-ro, Incheon, South Korea, jennsy@stanford.edu