Towards understanding digital support contributing to climate neutral, inclusive, and beautiful cities: A systematic literature review

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***Abstract*—Climate change is an existential threat to Europe and the world, and is impacting and influencing people. At the same time, the urbanization of the world is increasing, meaning that these challenges need to be solved mainly in cities. Cities are also increasingly using digital technologies to become smarter, which will be a crucial part of the future cities. The EU has initiated the European Green Deal in order to overcome these challenges, and to make Europe the first climate neutral continent by 2050. A part of this is the EU Cities Mission aiming for climate-neutral transitions in frontrunner cities by 2030. The EU-funded project Creating Actionable Futures (CrAFt) bridges these ambitions with the New European Bauhaus principles, to ensure that climate-neutral transitions in cities will be sustainable, inclusive, and beautiful. This systematic literature review was performed to understand digital tools in this specific context.**

***Index Terms*—Climate Neutrality, Sustainability, Urban Transformations, Intersectionality, Diversity, Inclusion, Computer Science, Systematic Literature Review, Climate Neutral Digital Tools**

I. Introduction

Climate change and environmental degradation are existential threats to Europe and the world. By 2050, the European Green Deal wants to overcome these challenges to ensure that the EU has net zero emissions of greenhouse gases, and that no person and no place is left behind [1]. By the same year, a staggering 68% of the world's population are projected to live in urban areas, while today's number is 55% [2], [3]. On a worldwide level, the UN has set seventeen ambitious sustainability goals to reach by the year 2030 [4]. The SDGs explicitly include diversity and inclusion goals to transform the world to be fully inclusive of people with disabilities through the #Envision2030 initiative [5].

The EU is addressing key challenges with a mission approach in its new research and innovation framework programme. The EU Missions restructure research and innovation, and use new forms of collaboration and governance, including a stronger role for citizens. This includes the EU Cities Mission on Climate-Neutral and Smart Cities [6], which explicitly acknowledges that "climate mitigation is heavily dependent on urban action" and that it is critical to "support cities in accelerating their green and digital transformation". Out of this mission programme, 112 cities have been selected as frontrunners to solve the challenge of becoming climate neutral by 2030.

The New European Bauhaus (NEB) is an EU initiative on creative and interdisciplinary principles that aims to connect the European Green Deal to "living spaces and experiences" and to call "on all of us to imagine and build together a sustainable and inclusive future that is beautiful for our eyes, minds, and souls" [7]. The NEB principles are aesthetics, sustainability, and inclusiveness; which opens a path to include arts and culture into the transitions.

The EU-funded project CrAFt (Creating Actionable Futures) focuses on cities, by supporting them to become climate-neutral in a sustainable, beautiful, and inclusive way [8]. By this, it combines and bridges the approaches of the New European Bauhaus and the EU Cities Mission. The CrAFt project aims to develop experience-based knowledge with

three sandbox cities (Bologna, Prague and Amsterdam) and 60 Reference Cities engaged in testing and sharing knowledge together with cultural, artistic and creative sectors, property owners and tenants, and citizens and communities.

As Europe transitions to smart cities, a plethora of tools specifically designed to assess, track, and measure the impact people and businesses have on the environment have been developed, e.g. [9]–[11]. However, few studies were found that integrated the arts and culture, or the principles clustered in NEB, into smart cities tools.

Smart cities, with all their technological and digital tools, have been dubbed the future of urbanization and a solution for the growing population of cities [12], [13]. This indicates that technology will be integral to creating the cities of the future. Technology could play a major role in achieving the previously mentioned goals set by the EU and UN for cities and countries. They will also be an important contribution into the CrAFt project results, with the project's focus on (smart) cities. This paper will address how digital technologies can contribute to reaching these goals.

II. Background

More and more people are living in urban areas, which leads to changes in infrastructure including more buildings and more transportation. Estimates suggest that 75% of global greenhouse gas (GHG) emissions already come from cities [14]. As a result of increasing climate change, the European Commission aims to reduce GHG emissions by at least 55% by 2030, which will help Europe reach the goal of climate neutrality by the year of 2050 [15]. The European Green Deal aims at making Europe the first climate neutral continent. Involving the cities in climate actions is therefore expected to have a major impact on fighting climate change [14], [16].

Digital tools will play a vital role in achieving climate neutrality in cities. There are several definitions of what makes a city *smart*. Magalhães et al. [17] point at several definitions, but one claims that a smart city uses ICTs to make life in a city more interactive, accessible and efficient, and is therefore also pointing at the importance of inclusion of citizens in the smart cities. An industry report [18] defines that a city is smart if data and digital technologies are used to take better decisions and improve life-quality of the inhabitants. Other definitions include the transformative and social character, for example as "a convergence of digital information and physical environment along with social factors within a city", along key areas of "governance, people, living, mobility, economy, environment" [19]. The following subsections will provide an overview of important concepts, goals and initiatives currently supporting the work for sustainable and inclusive cities, and motivating the area of research.

A. Smart Cities Beyond Climate

The UN Sustainability goals have caused the UN and EU to look beyond gender in the creation of smart cities and dare to imagine what comes next. As we have seen with gender, representation can shape the technology and digital tools we see in the future, and gender equity is now a criterion for receiving public funding. The EU has created action plans that can be implemented as a means of operationalizing and tracking gender balance over time [20]. However, when we think of diversity, we need to think bigger than just gender.

Intersectionality, first defined by Crenshaw in 1989 [21], is the idea that people are judged on more than just one character trait in isolation. Instead, all of the unique traits that make a person shape their experiences and possible biases and stereotypes applied to them. This includes visible traits like race, physical disabilities, and gender presentation, but unique traits also include concealable stigmas. Concealable stigmas are social stigmas carried inside a person and are not discernible unless they are voluntarily disclosed [22]. These include sexual orientation [23], health issues [24], and mental illnesses [25]. These and other marginalized communities [26] are often excluded from the transition to smart cities. Globally, recognizing diversity and inclusion can have a profound impact on the world we live in, and this plays a vital role in the smart, sustainable cities of the future.

B. Smart Sustainable Cities

The concept of smart sustainable cities emerged in 2011 [19], [27]–[29], and the concept is gaining attention as a potential answer to the aforementioned challenges of climate in cities. Earlier references have been made to the smart cities and the sustainable cities, but there is a lack of connection between the two concepts. The paper by Bibri and Krogstie also states that ICT has taken an important place in the debate on sustainability in urban areas, based on the already massively used urban ICT solutions. However, they claim that the smart solutions in cities are being used without making contributions to sustainability, and that the sustainable city solutions are not being smart [29]. For example, Höjer and Wangel [30] define a Smart Sustainable City as a city that

- "meets the needs of its present inhabitants
- without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and
- where this is supported by ICT."

With this working definition in mind, it is possible to evaluate the United Nations Sustainable Development Goal 11 in context.

C. SDG 11: Make cities inclusive, safe, resilient and sustainable

In the UN's 2030 Agenda for Sustainable Development, which lays out a shared roadmap for peace and wealth of people and the planet today and in the future, the 17 Sustainable Development Goals (SDGs) are at heart. "Goal 11: Make cities inclusive, safe, resilient and sustainable" focuses on the challenges concerned with massive urbanization and that there is a need for new, intelligent urban planning to overcome those challenges [31]. Research on SDG11 has covered many topics from addressing challenges [32], examining whether the goal

is attainable [33], creating a framework for scaling indicators [34] and evaluating the role of protocols [35]. As smart cities are emerging, however, digital technologies will also play an important part in reaching SDG11.

Artificial Intelligence will play a vital role in smart sustainable cities. The forthcoming book *The Ethics of Artificial Intelligence for the Sustainable Development Goals* (2023) will cover ethical and governance issues relating to the development of AI solutions for the SDGs, and work by Gupta and Degbelo empirically analyses AI tools specifically relating to SDG11 [36]. Vinuesa et al. [37] also investigate the role of Artificial Intelligence (AI) in achieving the UN Sustainable Development Goals. 67 targets (82%) within the Society group of the 17 SDGs could potentially benefit from AI-based technology, according to the authors of this paper. Specifically for SDG11, AI could help provide the population with food, health, water and energy services. They also point out that AI could support the evolution of smart cities. The authors also identify 25 targets (93%) where AI can act as an enabler for the SDGs regarding environmental issues. Specifically, there is proof that AI will support the comprehension of climate change, and model the potential effects. The paper points out fewer targets that can be influenced negatively by AI, and how for instance advanced AI technology requires large computational resources, leaving a severe carbon footprint.

D. The New European Bauhaus

In the cities of the future, sustainability, inclusion and aesthetics will be important, inseparable values. The New European Bauhaus initiative calls on all European citizens to build together a sustainable and inclusive future [7]. It is an EU initiative and focuses on creativity and transdisciplinary work for the European cities to reach the goals of climate neutrality, as well as connecting it to our daily lives and focusing on inclusion and beauty. Furthermore, the initiative is described as following [7]:

- "It is a bridge between the world of science and technology, art and culture."
- "It is about leveraging our green and digital challenges to transform our lives for the better."
- "It is an invitation to address complex societal problems together through co-creation."

Society, the arts, and culture are brought to the forefront of climate neutrality in order to capture the uniqueness of cityscapes and create sustainable cities of the future. The NEB initiative is shaping CrAFt (Creating Actionable Futures) in practice.

E. CrAFt - Creating Actionable Futures

The CrAFt project [8], also briefly introduced in Section I, is connected to the New European Bauhaus initiative, and CrAFt focuses on urban stakeholders to place climate neutrality at their hearts. Based on experiences from CrAFt's 3 Sandbox Cities, namely Amsterdam, Bologna and Prague, and 60 reference cities, the project will support Climate City Contracts and their implementation. In order to leverage the value of

Fig. 1. Map of CrAFt cities [8]

inclusiveness, aesthetics and sustainability towards climate-neutral urban areas, the project expectation is to test and disseminate collaborative local government models. The cities involved in the cooperation project all over Europe are shown in Figure 1.

CrAFt inclusiveness also considers the cities. There is no such thing as an ideal city, hence there is not a single way of achieving climate neutrality or inclusion in cities. Each city must be treated individually, and the individual challenges of each city must be addressed, while using standardised solutions as far as possible. Only then it is possible to achieve the goals of climate neutrality for European cities [38]. In order to achieve these goals, citizens must participate in the process of creating policy and governance.

F. Citizen Participation

Citizen participation refers to the involvement of citizens in public decision-making [39]. This may include citizens as either individuals or groups of people, and participation can involve both observation and power. Some ways to encourage citizen participation include governments using mobile applications to engage citizens [40] as well as using information communication technologies (ICT) and the internet of things (IoT) to create a sense of place [41], inclusion in co-creation processes [42], or as active participants in the energy transition [43].

Citizen participation will be decisive in making the cities of the future, and is pointed out as one of the important aspects of the CrAFt project. Specifically, CrAFt will take advantage of citizens as the experts in everyday life in the city, and make them an important part of the project. CrAFt also aims to include diversity and inclusiveness as a core aspect of its work: "Through direct interaction with citizens and communities, property owners and tenants, cultural, artistic and creative sectors, and universities and schools of arts and design, CrAFt implements awareness raising and citizen-

science based strategies for public engagement that leaves no one behind." [38]. Citizen participation, the UN SDG 11, and smart cities developed the framework for the systematic literature review (SLR) examining tools that help in making cities climate neutral, beautiful, and inclusive.

III. Methodology

This systematic literature review (SLR) employs the methodology for evidence-based software engineering as described in Kitchenham [44] and demonstrated in Kitchenham et al. [45].

A. Research Question

To explore the literature available about digital tools that can assist in New European Bauhaus and CrAFt goals of making cities inclusive, sustainable, beautiful, and climate neutral, the following research question guided the design of this protocol:

What are the most common types of digital support contributing to climate neutral, inclusive and beautiful cities?

B. Database Selection

Based on the need to root future project development in empirical software engineering literature, only studies with full text access found in SCOPUS were included. To conduct the search of the studies, the SCOPUS database was selected, because it handles complex search strings and includes sources from different fields.

C. Query

The final query designed for this SLR was: *((“digital*” OR “digital support” OR “digital tools” OR “software” OR “digitali?ation” OR “digiti?ation” OR “app”) AND (“sustainable” OR “sustainability” OR “climate” OR “climate neutral” OR “inclusive” OR “inclusion” OR “enriching” OR “beautiful”) AND (“city” OR “cities”)).*

This query yielded 1280 results. Criteria to evaluate the studies were then applied.

D. Inclusion and Exclusion Criteria

Using Bibri and Krogstie's 2017 literature review [29] of digital tools for smart cities led to the decision to use the study as a basis for a new review instead of evaluating work that had previously been evaluated. Therefore, only studies published between January 2017 and December 2022 were examined for inclusion and exclusion. The titles, abstracts, keywords, and research questions were evaluated for alignment with the inclusion and exclusion criteria. The following inclusion criteria were used in the study selection process:

1) Papers that clearly present in either title or abstract the use of digital support aiming to contribute to either inclusion, climate neutrality or beautiful cities
2) Papers not specifically aiming at these aspects, but nevertheless clearly presenting digital support that could contribute to this initiative

Using these inclusion criteria produced 211 viable studies. Exclusion criteria were then applied. Exclusion criteria:

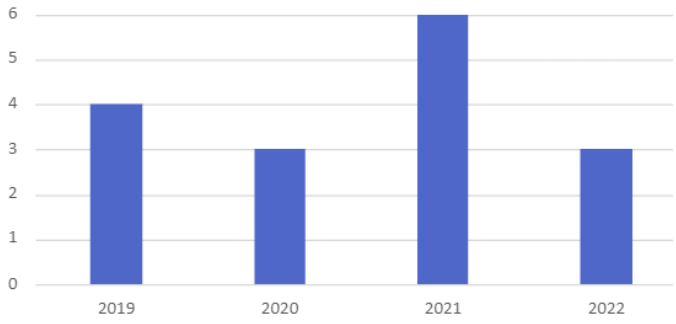

Fig. 2. Number of publications reviewed by year

1) Papers not written in English
2) Papers with typographical errors in the title
3) Papers not associated with the field of Computer Science
4) Papers behind paywalls that NTNU students could not access without special request (the library carries most major subscriptions)
5) Papers without author(s)
6) Papers without abstract
7) Papers from December 2016 or prior

Based on these criteria, 113 papers were selected for quality assessment and interrater review.

E. Quality Assessment

Two researchers scored the 113 papers using open coding and interrater reliability. The remaining papers were evaluated for relevance of addressing software engineering methods, design, and theory based on their research questions, aims, and areas of research. Papers were scored from 0 (no relevance) to 2 (highly relevant)

The results of the the interrater review included 30 papers with a 2-2 score which were selected to evaluate for further quality assessment with regard to relevance and scope of the research question. Further evaluation led to selecting studies that were empirical and included a detailed Methods section. This led to the selection of 16 papers for detailed analysis.

IV. Results

A. Findings

The distribution of publication years is shown in Figure 2 as 4 papers from 2019, 3 from 2020, 6 from 2021, and 3 from 2022. 9 of 16 papers are from the last two years 2021 and 2022. While only papers prior to January 2017 were excluded, no papers from 2018 met the criteria.

Figure 3 shows the distribution of countries where research studies were carried out. It is a world map depicting study site distribution in the papers evaluated. Across 16 studies, 20 study sites were represented, and 14 unique countries were identified as study site locations. Italy and Portugal were in three studies, the United States was a study site location in two studies, and the remaining countries were present in one study. An international study, which was multicultural in nature, is not depicted on the map as no specific countries

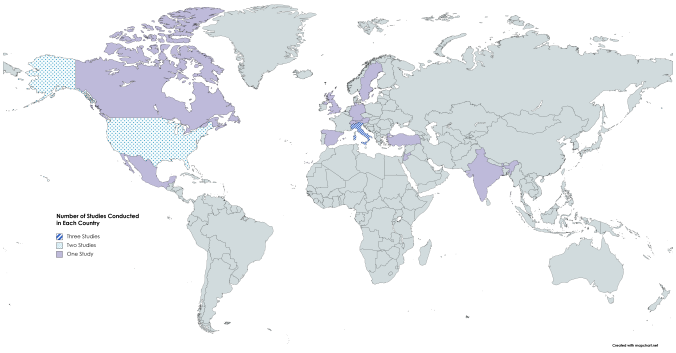

Fig. 3. Number of selected studies targeting countries

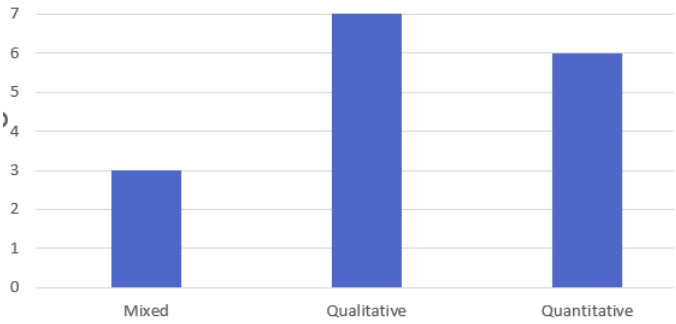

Fig. 4. Research methodology

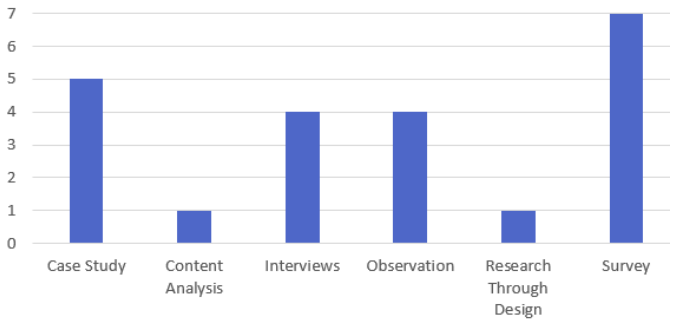

Fig. 5. Research instruments used

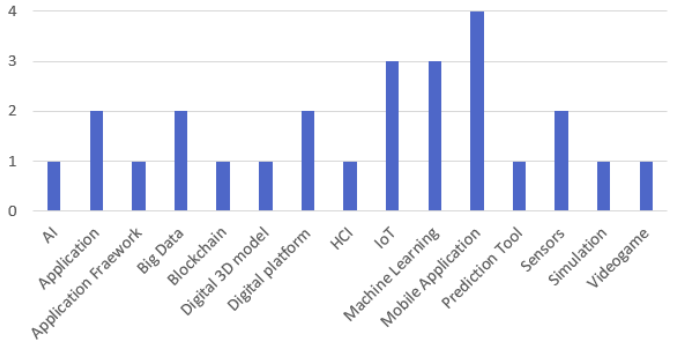

Fig. 6. Digital technologies contributing to research questions

were identified. The results show a skewed distribution, where 71% of the country distribution are in Europe, 21% are North American, and 7% are in South Asia. One of the papers does state a specific country, but it is an EU study. Of the obtained set of studies, no research from Africa, South America, Oceania, or the rest of Asia.

B. Research Methodology

Figure 4 shows the distribution of research methodologies used in the evaluated studies. 44% apply qualitative methods, and 38% use quantitative methods. While mixed methods is an often-used methodology in software engineering research, it only appeared in 18% of the papers.

As shown in Figure 5, the primary studies use several different instruments. The most used methodology in the evaluated studies is a survey, appearing in seven papers across all research methodologies. Case studies appear in five papers, meaning those results may not be generalizable or representative of all software engineering literature. Four of the evaluated studies used observation and interviews. Finally one of the papers used "Research Through Design" [46] as a methodology, and one study employed content analysis. The distribution of instruments used in the studies helps to inform the digital technologies evaluated or proposed.

C. Digital Technologies

To understand how digital technologies can be used in cities, it is of interest to know what the most common digital technologies used today are. This will provide valuable insights about what tools that will be decisive in the evolution of environmental, inclusive and digital cities.

Figure 6 shows the distribution of the main digital technologies presented, suggested, or developed in the evaluated studies. Only technologies that contribute to smart city development through climate neutrality, beauty, or inclusion, as aligned with CrAFt and NEB, were included in this analysis; therefore, some studies might also have used additional ones. Seven studies used more than one technology, so the total number of digital technologies exceeds the number of papers. As shown in Figure 6, Mobile Applications are mentioned in four papers, making it the most mentioned. Internet of Things (IoT) and Machine Learning were mentioned in three papers, and the broad categories Application, Digital Platform, and Sensors each appeared in two papers.

V. Discussion

This SLR was designed to examine the literature about software and the creation of digital tools that promote beauty, inclusion, and climate neutrality in smart cities. At the time the study was conducted, the most examined or designed digital technology in this dataset was the mobile application, which is used in 37.5% of the evaluated studies. This is followed by IoT and Machine Learning, present in 18.75% of the examined research. Applications, Big Data, Digital Platforms, and Sensors each appeared in 12.5% of the examined research. A mapping of the studies evaluated can be seen in Table I.

The evaluated research includes applications that authors have developed as a solution or intervention themselves, the evaluation of mobile applications, and studies where mobile applications are proposed as solutions based on empirical research. Gamification was specifically evaluated in 18.75% of the studies [47]–[49], and it has been proven to have successful implementations for citizen participation in smart cities. Luger-Bazinger and Hornung-Prähauser [48] present positive results from using gamification to make more climate-neutral choices, with no specific differences between men and women. Many kilometres of cycling instead of driving were a direct result of using this gamification application. These results indicate that gamification should be considered in making applications for citizen participation in the future, as they seem to successfully involve and engage people in the city.

Magalhães et al. [17] conclude that the digital medium best received by the citizen is the mobile application, based on a qualitative questionnaire aiming to collect feedback from the target inhabitants. This indicates that mobile applications should be considered when designing solutions for smart cities, especially to encourage citizen participation.

IoT and AI are equally used, and are the second most used technologies. In the examined studies, IoT is not used as an individual technology. Rather it is used with, mobile applications or big data. Varghese et al. [50] use IoT with app development and AI for making an app to reduce food waste, while Baghezza et al. [51] use IoT with machine learning to improve accessibility for people with reduced mobility. Finally, Bibri and Krogstie [52] highlight the potential opportunities offered by IoT and big data for environmental sustainability. There is a broad range of IoT-enabled applications that can be used in smart cities, and IoT solutions will be influential in the digital city solutions in combination with other digital technologies.

Several digital technologies can be used with different applications in software engineering research, showing that there are possibilities in making digital solutions for making the cities of the future climate neutral, inclusive and/or beautiful. The diversity of digital technologies used can be connected to the motivation for the CrAFt project, and the focus on every place having its own specific challenges and needs, and that there is no single way of making a city climate neutral or inclusive. The digital solutions applied must therefore also meet the specific characteristics of the city and its inhabitants in order to be effective and help move towards the aims. Therefore, when designing digital solutions for each specific city, effort must be made to customize the solutions which best fit for that specific city context.

To answer the research question *What are the most common types of digital support contributing to climate neutral, inclusive and beautiful cities*, the most common types of digital tools found in this dataset are mobile applications that encourage citizen participation. These tools can be used in a variety of ways including making cognitive behavioral changes and providing information about climate change, beauty, and inclusion. Users of applications may benefit from gamification elements, and they want to participate in the experience of creation. These findings inform the software engineering and design process by providing a direction for teams who hope to develop or improve processes in smart city creation and the transition to climate neutrality that is inclusive and aligned with the UN SDGs.

A. Limitations

A limitation with this study is the use of only one database (Scopus) in the process of collecting relevant studies. Although Scopus includes a wide coverage of studies from different disciplines, including different databases like IEEE or ACM may show additional studies and an overlap of digital tools, technologies, research methods, or study site locations that may have been overlooked. Based on a deeper analysis of the results, an adaptation of queries or search strategies may also uncover further relevant works. As mentioned by reviewer 1, the query should have included the terms ”green through,” ”green by,” ”energy consumption,” and ”energy efficiency” as synonyms for climate neutrality. However, when these were added to the query in SCOPUS, no results were found. Perhaps including these terms in other databases will produce different results. This paper presents an initial study only, and future work is needed.

Apart from scientific articles, the developing NEB ecosystem makes more information available. For example, digiNEB is collecting examples of digital tools[1] that could be included in followup studies.

VI. Conclusions

It is clear that some digital solutions to examine, address, or assist with citizen engagement and the creation of smart cities are already available. While these digital tools promote either climate neutrality, beauty, or inclusion, only one study in this SLR bridged across the New European Bauhaus values. No studies examined included all three aspects. Therefore, future research in digital solutions and tools developed for citizen engagement and participation in the creation of smart cities should include all three dimensions.

In order to make sure no person is left behind, inclusive solutions should be designed from with gender balance and intersectionality in mind. Special effort to include marginalized communities and vulnerable populations in the design and co-creation process of digital tools [53] will help ensure a variety of needs are heard and included in smart cities of the future. The goal to reach climate neutrality is ambitious, but it can be achieved by designing through co-creation and citizen participation in order to have a sustainable, inclusive, and beautiful future.

Acknowledgment

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[1] https://digineb.eu/digital-toolkit

[2] https://craft-cities.eu/

TABLE I
MAPPING THE STUDIES BY AREA OF RESEARCH, TOOL, LOCATION, AND METHODOLOGY

Study	Year	Area of Research	Digital technologies	Location	Methodology	Instrument
[51]	2022	Inclusion	Machine learning/IoT/Sensors	Canada	Quantitative	Observation
[52]	2020	Climate Neutrality	Big data/IoT	Sweden/Spain	Qualitative	Case Study
[54]	2019	Climate Neutrality	Video game	Italy/Turkey	Mixed	Survey/Case Study
[55]	2020	Beauty	Big Data/Sensors	Italy	Qualitative	Case Study
[56]	2020	Climate Neutrality	Digital Platform/Simulation	Mexico	Quantitative	Observation/ Case Study
[57]	2021	Beauty	Application framework/Machine Learning	Switzerland	Quantitative	Survey
[47]	2019	Climate Neutrality	Mobile Application	Italy	Mixed	Observation/Survey/Interview
[48]	2021	Climate Neutrality	Mobile Application	Austria	Quantitative	Observation
[17]	2021	Inclusion	Mobile Application	Not Stated	Qualitative	Survey
[58]	2019	Inclusion	Digital Platform	Germany	Quantitative	Content Analysis
[49]	2022	Climate Neutrality	Mobile Application	Portugal	Qualitative	Survey
[59]	2021	Inclusion	Application	EU	Mixed	Research Through Design
[60]	2019	Inclusion	Blockchain	Portugal	Qualitative	Interview
[61]	2021	Beauty	Digital 3D model	Jordan/India	Qualitative	Interview/Case Study
[62]	2022	Climate Neutrality & Beauty	Machine Learning/Prediction Tool	UK/USA	Qualitative	Survey
[50]	2021	Climate Neutrality	Mobile Application/AI/IoT/HCI	USA	Qualitative	Interview/Survey

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