Technology in Society 75 (2023) 102397

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

# A literature review of smart technology domains with implications for research on smart rural communities

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ARTICLE INFO

*Keywords:*
Literature review
Smart technology
Smart technology domains
Smart rural communities
Sociotechnical
Empirical

ABSTRACT

This literature review examines empirical research on smart technologies in eight domains and seeks to analyse implications for smart rural communities research. The development and implementation of smart technologies has the potential to improve various aspects of life in rural areas, including healthcare, mobility, and governance. However, the adoption of these technologies also raises important questions about their relation to communities. The existing literature is reviewed to examine the key findings and knowledge gaps. By using a sociotechnical perspective and considering the specific characteristics of rural communities, the discussion is focused on how smart technologies can contribute to rural contexts. Further, policy implications are considered, encompassing the requirement for a holistic and inclusive approach to the implementation of smart technologies in rural areas. Implementation should address the specific needs, challenges, economic and infrastructural conditions, social structures, and cultural contexts of the respective communities. Future research and exploration of smart community concepts in rural contexts are suggested to improve smart technology implementation.

## 1. Introduction

The development of smart technologies has impacted various domains, from healthcare and transportation to energy and mobility. These technologies, which include artificial intelligence, the Internet of Things, and sensors and data analysis, have the potential to improve efficiency, productivity, and safety. However, their adoption also raises important questions about their relationship to communities, the environment, and the economy.

In this research, the aim is to explore the potential benefits and drawbacks of smart technologies, as well as the challenges and opportunities they present to different domains. The review includes existing empirical research on the topic, along with case studies of the implementation of smart technologies in various settings. Ultimately, the goal is to provide a better understanding of the potential role of smart technologies in the future of smart rural communities.

Rural communities are of a particular concern within Europe [1]. Rural areas are home to 137 million people representing almost 30% of its population and over 80% of its territory, considering all communes and municipalities of Europe with low population size or density. They are important for food production, sustaining natural resources, protection of natural landscapes, and recreation and tourism. Still, communities in rural areas face many challenges because of globalisation and urbanisation. Challenges include lower gross domestic product per person, lower employment rate, lower share of people with higher education, lack of infrastructure, access to facilities and amenities, digital connectivity, and employment opportunities. However, new society demands, possibilities of the green economy, digital technology, consequences of the COVID-19 pandemic and the increase of teleworking have brought attention to rural areas as places of well-being, security, eco-living, and new possibilities for social and economic renewal. Succeeding with smart rural communities therefore resolve some key challenges for the society and has many potential upsides.

In recent years, the term "smart" has been frequently used in describing different digital technology initiatives in certain domains. Smart cities is a prominent example. In this review study, the state of empirical research on technology implementations across the following eight smart technology domains are investigated: *smart cities, smart community, smart health, smart farming, smart tourism, smart mobility, smart energy*, and *smart governance*. Key motivations for this paper are to contribute to the knowledge of smart rural communities and to mitigate a potential urban bias when implementing smart technologies in non-

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https://doi.org/10.1016/j.techsoc.2023.102397
Received 21 December 2022; Received in revised form 29 September 2023; Accepted 15 October 2023
Available online 27 October 2023
0160-791X/

urban areas. This study aims to contribute to the development of such knowledge, by investigating the current state of empirically oriented smart technology research across different domains.

The review focus on empirical research for two primary reasons. First, because the study seeks to avoid the technological determinism reported to be a problem in the smart city studies [see e.g., 2]. Technological determinism is a perspective in which technology is considered an independent, value neutral force that brings about change. A deterministic perspective stands in contrast to sociotechnical understandings of how digitalisation occurs. In a sociotechnical (sometimes referred to as socio-constructivist) perspective technology and communities are considered to influence each other [3,4]. Technology contains values, not always in accordance with users' values. For technology to be successfully used in a domain or community, these values need to be aligned [5]. Second, building on the first point, to understand to which degree a certain technology fits into a domain and how it is used, investigators need to engage with the real world. This can be done through empirical research.

Having an empirical, sociotechnical focus is particularly important to the domain of smart rural communities. While the concept for smart urban communities is quite well established, e.g., smart cities, the concepts of smart rural communities and smart village are still rather underdeveloped [6,7]. Smart rural communities can be understood as:

> "Rural areas and communities which build on their existing strengths and assets as well as on developing new opportunities. […] traditional and new networks and services are enhanced by means of digital, telecommunication technologies, innovations and the better use of knowledge for the benefit of inhabitants and business" [8].

Smart technologies aim to address some of the challenges faced by rural communities. Research suggests that improved connectivity and creating digital environments for innovative services, economic sustainability, jobs, and social capital can contribute to vibrant and liveable rural communities [9–11]. However, it is increasingly evident that achieving the ambitions of smart rural communities requires more than just technological advancements. It necessitates a similar focus on community development, including service innovation and the development of digital capabilities and skills.

Current research on smart rural communities consequently argues for a sociotechnical approach to technology implementation [7]. It is recognised that successful technology implementation requires a deep understanding of the social, cultural, economic, and infrastructural aspects of these communities [12]. A community-centred approach to development is proposed, emphasising that sustainable living in rural areas cannot be achieved through technological solutions alone. To ensure sustainability, appropriation, and effectiveness of new solutions in the long term, the process must be initialised, adapted and led by people and their needs [12]. Also, aspects of smart city research suggest that involving key stakeholders in the process is paramount [13,14]. By adopting a community focus, researchers are also challenging the dichotomy between smart cities and smart rural areas. Granath et al. [7] argue that many regions around the world are characterised by towns and villages rather than large mega-cities, and the challenges and opportunities in these areas differ from densely populated societies. Additionally, current trends in urban planning and digital transformation underscore the need for a stronger emphasis on sustainable development [15]. Given this backdrop, it becomes evident that rural cases of smart technology implementations and use are both important and relevant.

Based upon the above background of learning from smart technology domains and taking a sociotechnical perspective on smart technologies, the following research questions guided the research.

- RQ1 What are the main findings and knowledge gaps of the existing literature on smart technology domains?
- RQ2 What implications does the sociotechnical perspective have for the study of smart technology domains?
- RQ3 How can the sociotechnical perspective contribute to advancing research on smart rural communities?

To answer these research questions, this study reviews research covering several smart technology domains. The review study was organised in two steps: First, an umbrella review was conducted, where the search was limited to existing literature reviews that had their basis in empirical primary studies. The rationale for this is twofold: To focus on those reviews that have a direct relevance for the goal of this study, and to get a result of papers that focused on actual implementations of smart technology. Second, empirical primary studies were supplemented in domains that did not have any literature reviews.

The paper aims to contribute to smart communities' research in the following ways. First, an analysis of research objectives and research questions are provided (section 3.1). This seeks to provide an overview of how smart technology domain studies are rigged and what has been the focus to date. Second, an analysis of forms of smart technologies and in which domains they are investigated is presented (section 3.2). Third, key findings and knowledge gaps within each smart technology domain are summarised (section 3.3). The section concludes with an analysis of aggregated knowledge gaps, pointing towards relevant avenues for smart rural communities research. The discussion section engages with these findings, provides a sociotechnical consideration of the smart technology domain research, and discusses implications for a sociotechnical perspective on smart rural communities. Practical implications in the domain are also provided.

The rest of the paper is organised as follows: Section 2 presents the materials and methods for this study, describing the search, the screening process, and literature assessment and analysis. Section 3 and provides research objectives and research questions, a summary of which smart technologies are described, and an analysis of key findings within each smart domain. Section 4 discusses the implication of the findings on research on smart domains from a sociotechnical perspective and discuss implications for sociotechnical research on smart rural communities. More practical policy recommendations are also discussed. Section 5 concludes the study.

## 2. Materials and methods

This paper has used two primary methods. An umbrella review and a supplementary literature search. These are explained below.

An umbrella review is a method suited for summarising evidence from multiple research synthetases, "conducted to provide an overall examination of the body of information that is available for a given topic, and to compare and contrast the results of published systematic reviews" [16,17, see also 18,19]. Starting from these systematic- or meta-analysis, umbrella reviews typically "seeks to impose an overall coherence by lumping these precise reviews together" [18], resulting in a compilation of existing reviews providing a higher-level overview. Following this rationale, the objective of this undertaking was to map the status of empirical research within the relevant smart domains for this study, and to point to recommendations for future research.

In addition to the umbrella review, it was conducted supplementary literature searches for empirical primary studies within the domains where there was no or not enough literature reviews meeting the criteria set for the umbrella review. This concerns the domains of smart community, smart health, smart tourism, smart farming, smart energy, smart mobility, and smart governance. For this study, a cut-off limit value for each domain to three papers minimum were set.

### 2.1. Screening process

#### 2.1.1. Umbrella review

The umbrella review guidelines of Aromataris et al. [16] were followed for this study. In the initial phases, a review protocol was developed. This protocol includes screening and selection criteria, as well as bibliographical data[1] and information such as background and content of the publication. Fig. 1 shows the step-by-step umbrella review process. The literature search was conducted May 4th, 2022. First, a set of keywords were defined for each of the scoping domains. These keyworks were subjected to searches within the databases Scopus and Web of Science (see Table 6 in Appendix). The keyword searches yielded a total of 90 results across the eight domains.

The first round of screening consisted in duplicate removal form the two databases. Then, an abstract screening was conducted, assessing the relevance of the papers based on the abstract text. The selection was done by a team of four researchers, and the screening process and consensus meetings were documented, including writing down reasons for inclusion and exclusion.

After the abstract screening, 32 papers were included for a full-paper assessment, where papers were subjected to a more comprehensive, in-depth screening. During the full-paper screening, there was also conducted a qualitative assessment of the paper's relevance across domains, resulting in the reposting of secondary domains annotated to the publications. 18 of the 32 papers were identified as relevant to the scope of this study.

#### *2.1.2. Supplementary literature search*

For the supplementary literature search, Scopus and Web of Science databases was scanned using the same search term as for the umbrella review literature searches for each of the domains, but without the inclusion criteria of the document type as a review (criteria 2 in Table 1).

Selection and screening criteria for the supplementary literature search were as follows: In the initial screening of the supplementary literature, their relevance was assessed based on 1) the number of citations, and 2) whether the paper covered technology-in-use or use cases or data on technological implementations. The number of citations was used as a criterion for sorting the results in the databases, where the papers with the highest number of citations were assessed first. The question of whether papers covered technological aspects were investigated through the abstract- and full-paper screening.

All publications by the search date (May 4th, 2022) were included. A cut-off limit of three papers within each domain was set, were the three most cited were taken in. To meet the cut-off limit set for each domain, a total of 11 papers were included as part of the supplementary literature search (see Table 2 for overview).

After inclusion of papers from the supplementary literature search, 29 papers were finally included in the qualitative synthesis.

### *2.2. Literature assessment and analysis*

A group of three researchers performed the paper assessment, data extraction and analysis, using Microsoft Excel version 16.67, and following a consensus-based expert elicitation process. These researchers had different backgrounds and expertise, ranging from software development, information systems, fisheries and aquaculture science, and sociology. Each paper was assessed by a least two researchers, both in the abstract- and full-paper screening.

After the paper screening followed the extraction of bibliographical and qualitative data, addressing the research questions of this study. At least two researchers validated the results from each paper. Consensus meetings were held when discrepancies arose. The guidelines from Aromataris et al. [16] were followed for data extraction. The data was synthetised into descriptions of each smart domain, recapitulating the trends of the research associated to the respective domains.

Based upon the extracted data, several analyses were conducted. First, to analyse the objectives and the research questions of the included studies, the studies were mapped into cross-domain categories (see section 3.1.1 and 3.1.2). The research questions were summarised for each category respectively. Second, for technology, categories of technologies as described in the papers were identified, and which technologies were described in which smart domain was analysed (see section 3.2). For each smart domain key findings and knowledge gaps were summarised (see section 3.3). Third, knowledge gaps writ large across the different domains were analysed (see section 3.3.9), by mapping knowledge gaps identified in individual studies and domains to seven higher-level categories (see section 3.3). The categorisation was based on recurring themes and commonalities found across the reviewed literature. Further, these knowledge gaps were connected to a socio-technical perspective (see section 4.1), with the aim of showing the ways such a lens can contribute to addressing knowledge gaps, and thus contribute to smart rural communities research.

## 3. Results

### *3.1. Research focus in existing literature*

#### *3.1.1. Research objectives and research questions from the umbrella review*

Fig. 2 below shows the categories emerging from the analysis of the objectives of the umbrella review. The categories with the accompanying research questions are explained below.

The largest category of research objectives were papers aiming to provide an overview of the smart technology domain. This category contains the studies which aimed to provide an overview of state-of-the-art on the research field associated to a certain domain, pointing to knowledge gaps within existing research, and potentials avenues for future research [21,26–29,32,44,45]. For example, Zhao et al. [21] consider the most "noticeable developments", the "major focus area" and the "most important research areas" that has been overlooked in smart city research [24].

In terms of research questions, several studies did not provide or explicitly state a research question [27,32,41,44] which is typically considered a weakness when assessing the quality of review studies. However, among those that did provide research questions, questions sought to identify main trends within a domain [21,22,25,26,29,43]. These studies identify knowledge gaps and needs for future research, such as e.g. Abduljabbar et al. [29] who consolidates knowledge on micro-mobility in the smart city domain, analyses past and on-going research developments, and provides future research directions for micro-mobility as part of a sustainable low carbon mobility framework for future cities.

The second largest category of research objectives were papers investigating the maturity level of technologies in a domain. This category contains studies which focus on mapping the maturity level of a smart technology within a certain domain, such as Brohi et al. [22] reviewing big data technology within the smart city domain. Another example is Khosrojerdi et al. [25] exploring AI and analytics in smart energy grid projects [see also 28,42]. By considering the maturity level of various smart technologies, this category of studies seeks insight into the current state of these technologies and identify knowledge gaps.

The research questions encompass various aspects of technology integration and utilizations. They investigate the application of big data technologies (BDTs) in smart cities, the relevant publication outlets, and the maturity of this research domain. Additionally, they explore the types of analytics used in smart cities and seek to understand the current state and future directions of big data research in this context. Furthermore, they examine trends in Smart Grid projects that incorporate intelligent systems and data analytics, assess the business value of AI-based methods, and explore how these systems combine with data analytics. One paper considers the evolution and current trends in living lab research and inquiries about the methods and tools employed in user involvement. Lastly, they consider the maturity of agent-based modelling in the study of urban district energy systems.

[1] Title of publication, authors, year of publication, and journal name.

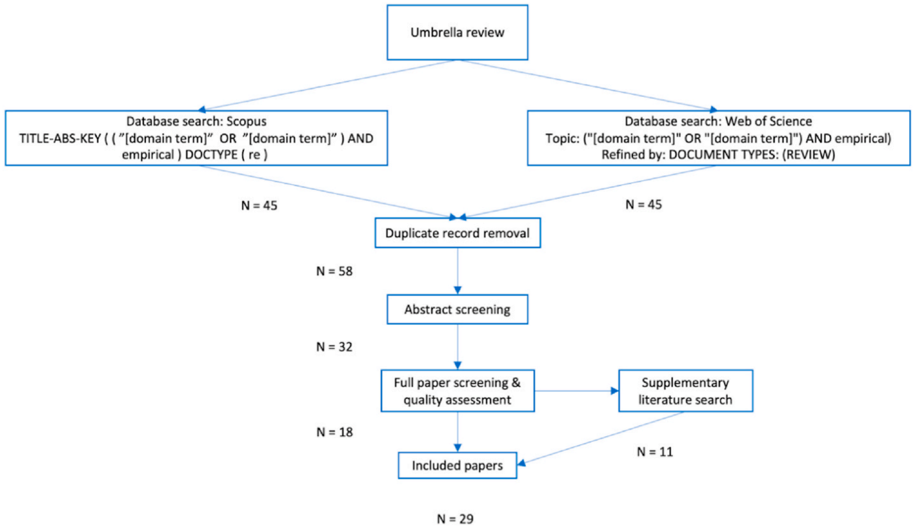


**Fig. 1.** Umbrella review literature flow chart.

**Table 1**
Selection and screening criteria.

| # | Inclusion/ exclusion | Criteria |
|---|---|---|
| 1 | I | Title, keyword list, and abstract makes explicit that the paper is related to [topic/domain] |
| 2 | I | The paper is a review paper |
| 3 | E | The paper is duplicate |
| 4 | E | The paper's full text is not available for download |
| 5 | E | The paper does not cover or review primary studies/ empirical studies |
| 6 | E | The paper does not cover the respective domain |
| 7 | E | The paper does not cover or review smart technology implementations or technology in use |

**Table 2**
Overview of papers included from the different literature search and assessment processes.

| Domains | Umbrella review literature search results | Supplementary literature search result |
|---|---|---|
| Smart City | [20–29] | |
| Smart Communities | | [2,30,31] |
| Smart Health | [32,33] | [34] |
| Smart Farming | [35] | [36,37] |
| Smart Tourism | | [38–40] |
| Smart Energy | [22,25,41,42] | |
| Smart Mobility | [29,43–45] | |
| Smart Governance | [22,23] | [46–48] |

The third category of research objectives were related to the investigation of technology potential for concrete challenges in a domain. This category of studies investigates the potential of smart technologies in solving concrete issues and challenges within specific domains [20,33,35]. Examples include the impact of digital technology on smart governance, how physical ICT solutions can help overcome loneliness and social isolation [33], smart sustainable mobility [43], moral values and the acceptance of smart grid [41], and cyber resilience [24].

These research questions in this category seek to understand various aspects of smart technologies targeting specific applications. They investigate the smart city approaches used for climate change adaptation, the benefits of such applications, and sociotechnical perspectives on addressing loneliness and social isolation among older adults through digital solutions. Furthermore, they explore the scientific evidence supporting claims about the impact of digital agricultural technologies on ecosystem services, inquire about smart mobility, and seek to define smart mobility comprehensively. They examine existing frameworks and systems in smart cities concerning cyber resilience, digital forensics, and incident response, including their empirical evidence and cross-sector applications in improving cybersecurity. Overall, these questions address challenges such as climate change, social well-being, agriculture, mobility, and cybersecurity.

**Table 3**
Overview of technologies mentioned in the included papers.

| Technology | Authors |
|---|---|
| Big data | [2,21,22,24,28,29,35,37,43,48] |
| Sensing technology (IoT, monitoring systems etc) | [2,22,24,26,27,29,30,32,34–36,40,41,43] |
| Software applications | [20,27,28,32,39,42] |
| Connectivity (communication systems, LoRa, RFID) | [33,35,43,44] |
| Telematics, positioning technologies | [39,43] |
| Hardware and software systems (Robotics, drones, autonomous vehicles) | [21,32,33,37,39,43,45] |
| Data analytics solutions | [20,29,30] |
| Emerging technologies (Artificial intelligence/ machine learning) | [25,27,29,34–36,40,41,43,45] |
| Information and communications technologies (ICT) | [2,20,21,23,27,28,30–34,38,40,41,43,44,46–48] |

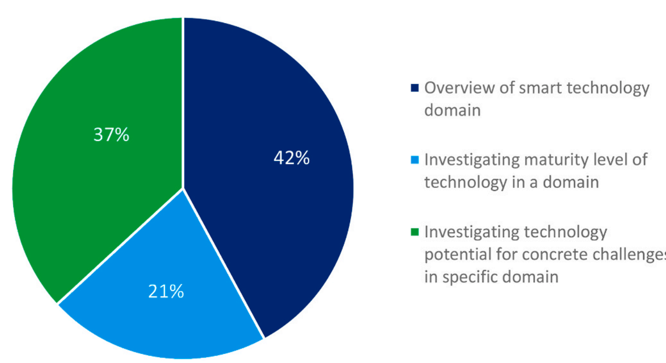


**Fig. 2.** Categories of objectives in umbrella review literature.

#### 3.1.2. Research objectives and research questions from the supplementary review literature

In the review of primary studies, the objectives were to contribute to new empirical evidence. Overall, they can be categorised as either conceptual studies or empirical case studies of a technology in use. Fig. 3 below shows the categories emerging from the analysis of the objectives of the umbrella review. The categories with the accompanying research questions are explained below.

We identified three categories of research objectives across the supplementary review literature, which were in turn relatively equally distributed across the reviewed literature.

One such category accommodated studies engaging in a conceptual discussion with the aim to enrich previous studies. Four of the studies are on a conceptual level/discussion or aim to enrich previous studies on domains [2,37,48], such as Caputo et al. [31] aiming to supplement studies on digital ecosystems with contributions derived from the studies on smart communities.

In terms of research questions in this category, they seek to understand the creation of user profiles and their abilities to use smart city services, explore user perceptions and the value they associate with these services, and address concerns about security, privacy, and ethics in the context of smart cities. Additionally, they investigate examples of good practices and user perceptions regarding the impacts of advanced ICT on smart city infrastructure. Furthermore, they inquire about the sustainability and policy implications of an evolutionary maturity model for smart city research. Another set of questions focuses on improving the management of digital ecosystems using smart community principles, examining the contributions of ICT to digital ecosystems. Lastly, they explore how ICT can promote collaborative governance and increase participation and engagement in smart city initiatives.

Another category were studies exploring the potential of a technology to improve a service or a solution. Four studies explore the potential of a method for increased efficiency or quality of service or solution, [30,34,36,40]. For example is the paper of Lee et al. [30], aimed to improve the privacy of smart home systems. Only one study included in this category posed a research question [40], and it concerned tourists' preferences of smart tourism services in tourist attractions.

The last category included studies assessing the impact of smart technology in a domain. Four studies focused on the impact or contribution of a certain technology on a certain domain [38,39,46,47]. For example, the objective of the study of Bonsón et al. [46] was to measure the impact of media technologies on stakeholder engagement in the smart government domain.

Research questions here investigate the factors influencing user behaviour and the effectiveness of certain technologies in certain domains. They explore the relationships between perceived value, information reliability, enjoyment, and travel information searches in social media usage. Also, they focus on the effectiveness of 3D maps for location-aware recommendations on mobile devices and whether location-awareness enhances system quality and usefulness. The final set considers the impact of different media and content types on citizen engagement and whether communicational differences exist across various public administration styles.

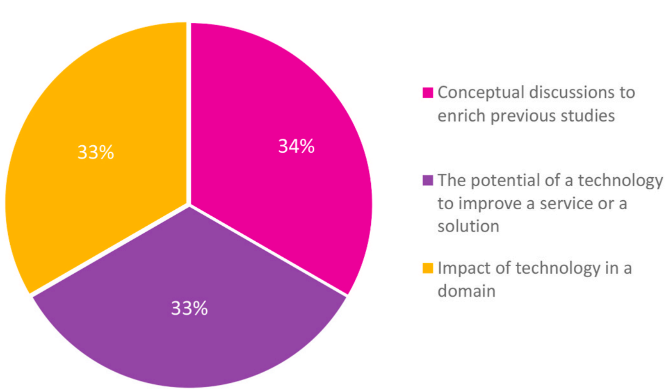


**Fig. 3.** Categories of objectives in supplementary literature.

On a final note, five of the eleven primary studies did not provide research questions [30,34,36,37,47].

### 3.2. Technologies investigated

In Table 11 (see Appendix), an overview of the technologies investigated in the included studies is provided. Table 3 displays the number of articles that mentions each technology,[2] while Fig. 4 provides an overview of the distribution of technologies across the domains.

Among the articles reviewed, 14 focused on sensing technology, 19 on information and communication technology and 11 on big data technology. While majority of the studies focused on Information and Communications Technology (ICT), only a few studies discussed data analytics solutions and telematics, the latter including global positioning systems (GPS). AI and machine learning literature often cites sensing technology, big data, robotics, drones, and autonomous vehicles. Furthermore, some studies focused on specific technologies to solve an issue within a domain, such as renewable energy [42], living labs [28], smart grid [41], and ambient assisted living [33,34] while other studies have a more holistic approach covering several technologies or issues concurrently [2,29,32,35,43]. This is relevant for the case of smart rural communities as these technologies can play a significant role in addressing the specific challenges faced by rural communities, such as connectivity, access to services, sustainable development, community engagement, and efficient resource management. Furthermore, sensing technologies can enable monitoring systems and IoT applications in the processes of various rural business sectors, environmental monitoring, and infrastructural management in rural areas.

In terms of a user-provider perspective, seven articles discussed technology from a user perspective. Several studies investigate the adoption of technology amongst different user groups, like tourists [38,40], patients [32,33], households [30] or citizens [46,48]. Others are interested in technology from a provider perspective [22,25,26,29,36,39]. The user-provider perspective covered in these studies, highlights the importance of considering the needs, preferences and experiences of both end-users and the entities responsible for implementing and managing smart technologies in rural communities. This dual perspective ensures that the technology solutions are user-centric and aligned with the specific requirements and contexts of rural areas.

Based on this analysis of the technologies investigated in the reviewed literature, future research on smart technology implementations in rural communities should aim to broaden the focus beyond ICT and e.g., explore the potential of data analytics solutions, telematics, and other emerging technologies. A user-provider perspective should be maintained to ensure user-centricity and effective implementation. Targeted investigation into specific technologies and their applications in rural domains can lead to tailored solutions, while a holistic approach considering multiple technologies and issues concurrently can address the complex challenges faced by rural communities. By addressing these implications, future research can pave the way for sustainable and inclusive smart technology implementation in rural settings.

### 3.3. Key findings, and knowledge gaps

In the following, the findings and knowledge gaps are presented in the included studies.

[2] The categorisation is based on an inductive approach by the authors and hence is not exhaustive. Papers sometimes note more than one technology, so the counts do not sum up to 31 (that is, the number of papers included).

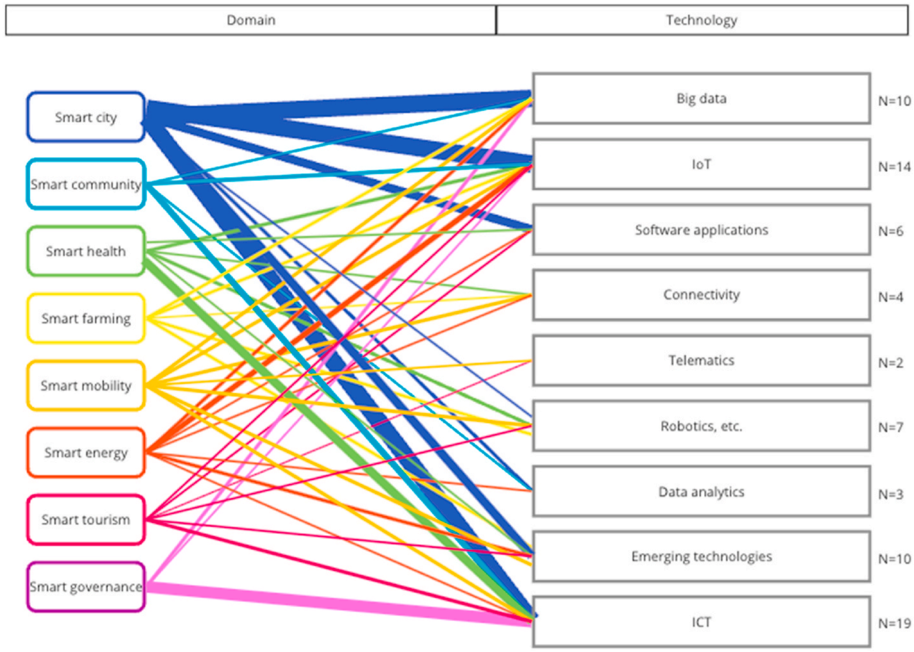


**Fig. 4.** Smart technologies distributed across smart domains. N marks the number of papers referring to each technology respectively. The line width indicates the number of papers from a research domain that refers to each technology.

#### 3.3.1. *Smart city*

The concept of smart cities is continuously evolving, yet the literature indicates that a consensus on its precise definition remains elusive. One highly cited definition describes a smart city as "a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership" [49]. Smart city research encompasses a wide range of applications and spans various sectors. Consequentially, several of the literature reviews explore the intersection of smart city with other domains, such as smart governance [23] or smart energy [25]. Some reviews specifically focus on smart mobility and transportation in urban settings, indicating a growing body of literature on sustainability aspects, such as micro-mobility "as a low-carbon and transformative mode of urban transport" [29]. Other studies adopt a multi-domain approach, investigating the connections between the concepts of smart city and sustainability [see e.g., 22].

Sustainability and climate change adaption are recurring research topics within the smart city domain, particularly in conceptual studies where environmental or sustainability aspects are often integrated. One study identifies environmental (ecological) sustainability as one of the primary categories in smart city literature [27]. Another study suggests that an integrated approach to smart cities and combating climate change is not only possible but also beneficial [20].

Several review studies concentrate on big data research in smart cities [2,21,22,24,28,29], often closely intertwined with sustainability. There is significant research activity in the areas of smart transportation and environment, while emphasising the need for additional efforts in smart healthcare, smart governance, smart safety, smart education, and smart energy to address the diverse challenges faced by smart cities [22]. Other studies are more technical. A pilot study survey finds that cloud services and local storage of big data enhance user satisfaction with smart city infrastructure [2]. Another study explores the integration of artificial intelligence and analytics in smart power grids [25].

It is important to note that smart city research is inherently multidisciplinary and spans multiple domains, leading to a fragmented literature with diverse perspectives [21]. The literature indicates that despite the close association between smart cities and sustainability in many review studies, there remains a need for more comprehensive literature reviews that encompass the breadth and depth of smart city research. Moreover, there is a distinct lack of research exploring the barriers and drivers that shape the engagement of local governments and citizens in digitally supported collaborations to accelerate sustainable transition in cities, an area that has been significantly underexplored [23]. Lastly, the limited discussion on the downsides of technology and the failure of smart city projects is defined as a knowledge gap within the domain [21].

#### 3.3.2. *Smart community*

While the concept of smart cities is quite well established, the concept of smart rural regions or communities are emerging worldwide [6]. In this study, the smart community domain is only found in the supplementary literature, and the term "rural" is notably absent in the findings. Additionally, none of the most cited papers address smart communities, but rather is in the smart cities domain [2].

One of the identified studies on smart communities emphasises the significant role of ICT in supporting interactions and information sharing within these communities [31]. The study, based on a literature review and analysis of the smart community domain in digital ecosystems (or networked environments), highlights how ICT enables decision-makers to better comprehend information and knowledge from various stakeholders [31]. Another paper introduces a platform for a smart home system, which is a crucial component of the Internet of Things (IoT) [30]. In their study, Lee et al. [30] propose a privacy-preserving smart home system that incorporates data collected from smart community environment and employs a privacy protection mechanism.

Regarding the identified knowledge gaps, they predominantly revolve around technological aspects. Lee et al. [30] for example suggests a more precise temporal division between public and private periods to enhance flexibility in settings. On the other hand, the study by Capito et al. [31] advocates for social, physiological, and economic researchers to effectively apply the principals of Digital Ecosystems in understanding and managing social configurations.

#### 3.3.3. *Smart governance*

The reviewed literature suggest that ICT solutions play a prominent role in the domain of smart government. Researchers emphasise the importance of ICT in facilitating information sharing and integration between government and citizens, ultimately empowering citizens and expanding democracy [46,48]. However, a study investigating e-government initiatives across European cities reveals that technology is only minimally utilised for two-way communication [47]. Findings suggested that "most municipal governments [seemed] to be at the billboard stage"; Most municipal governments are still in the initial stages of utilising web-based solutions to provide information to citizens, rather than engaging in interactive communication. Similarly, recent research concludes that "ICT-enabled government-citizen collaboration to advance urban sustainability, is still rare" [23], with one-way information flow being the dominant approach.

To enhance citizen engagement, smart government initiatives could benefit from facilitating more two-way communication on ICT platforms and services, such as allowing citizens to post on government social media [46]. Additionally, the domain of smart governance remains underexplored in terms of cyber-security research [24]. Despite the widespread use of social media platforms like Facebook, the impact of these platforms on government-to-citizen relationships lacks clear evidence [46]. Furthermore, the effects of smart government on sustainable urban development, specifically how ICT technology can support governments-citizen collaboration to accelerate sustainable transition, are identified as an underdeveloped research topic [23]. It is also crucial to address concerns related to the digital divide and the potential risk of social exclusion associated with the implementation of smart city and smart government initiatives [48]. Future studies should delve into the unintended consequences of these initiatives.

#### 3.3.4. Smart health

In the reviewed smart health research, various terms such as mHealth, Welfare Technology, Smart Home Technology, and Ambient Assisted Living technologies. These terms are used to describe the wide range of technological services and artefacts employed to enhance health prevention, diagnosis, treatment, monitoring and management of people's health, lifestyle and working environment, is applied. In their literature review, Zander et al. [32] provide a comprehensive overview of these technologies at different levels of scope and detail. This overview illustrates the complexity of the technological implementations comprised by the smart health domain, stretching from higher level categories like "smart home technology", to more narrow and specific technologies like e.g., robotic bathtubs, video outpatient consultations, or companion robots [32,33].

Latikka et al. [33] conducted a review study, addressing how technology can address loneliness and social isolation amongst elderly individuals. Their findings suggest that smart physical ICT solutions, including robots, wearables, etc., can assess and alleviate loneliness, which is especially relevant considering the covid-19 pandemic and restrictions. Another study examining the implementation of welfare technology, emphasise on the importance of understanding the drivers and barriers associated with technology adoption [32]. The authors propose an evaluation framework comprising six themes: capacity, attitudes and values, health, expectations, participation, and identity and lifestyle. They explore these themes from multiple perspective, including the person in need, informal caregivers, care personnel, organisational factors, and technological considerations. Bacciu et al. [34] presents a primary study that tests a reservoir computing model for tracking movement using radio signal strength [34].

Overall, the litterature suggest there is a need for future research in the field of smart health [22]. Particularly, there is a need for studies with robust designs and large data samples that explore technology implementation from individual and organisational perspective [32,33]. Experimental studies, such of the one conducted by Bacciu et al. [34], utilising real-world data are vital for addressing the challenges associated with introducing technological innovations into a practical setting. Additionally, knowledge gaps exist in terms of cyber-security research in smart health [24] and the need to understand user and organisational aspects of technology implementation [32]. Advancing stakeholder identification and engagement methods in technology implementation projects, particularly in an IoT context, is also an area requiring further development [32].

#### 3.3.5. Smart farming

Smart farming encompasses the utilisation of various technologies, including IoT, AI, and data analytics, within agricultural context to augment productivity, sustainability, and operational efficiency. Through the integration of sensors, robotics, and precision farming methodologies, smart farming can enable continuous monitoring, analysis, and automation of diverse agricultural processes. Benefits such as optimised allocation of resources, elevated crop yield, and minimised ecological footprint, are claimed to have the potential to change conventional farming methodologies, and laying the foundation for a more astute and sustainable agricultural sector.

In their review of Digital Agricultural Technologies (DAT), Green et al. [35] identifies three clusters of DATs: 1) technologies aimed at increasing precision in farm management (sensors, AI, robotics, etc.), 2) technologies focused on enhancing connectivity in the food system (supply chain management technologies, blockchain, etc.) and 3) technologies designed to create alternative food sources that could replace traditional agricultural practices (cellular agriculture etc.). Among these clusters, precision farming emerges as the most prominently discussed topic in the literature. In more detailed exploration, Jin et al. [36] present an experimental study introducing a hybrid deep learning predictor that incorporates two processes: Training and prediction. This predictor aims to improve the accuracy of climate data forecast (such as wind speed, temperature, and humidity) while reducing training costs. Taking a stakeholder perspective, Carolan [37] investigates precision farming within the context of digital agro-environmental processes and phenomena. Through interviews with employees from big data and precision farm equipment firms, Carolan examines the usage of data and the level of farmer access. The research highlights the interrelationships among stakeholders concerning access, property, and sovereignty, which can influence the political economy surrounding big data, precision farming, and smart farm equipment.

Addressing the lack of policies in the field, Green et al. [35] emphasise the importance of sustained investment in technical training, policies that incentivise the adoption of DATs, and research on sectoral and regional use scenarios for DATs to realise the anticipated benefits. Additionally, the need for research on more precise climate prediction in agricultural production is also highlighted [36].

#### 3.3.6. Smart tourism

The concept of smart tourism pertains to the utilisation of technology and data-driven solutions to enhance tourism experiences for travellers and optimise the management of tourist destinations [50,51]. In a study conducted by Noguera et al. [39], a specific tool is presented that provides location-aware recommendations on mobile devices. Through feedback received on the user interface, the study concludes that the system effectively meets the needs of on-the-move tourists, providing information on nearby points of interest, distances, and directions. The simplicity and usefulness of real-time, location-based recommendations support customers in their travel planning. Similarly, Chung and Koo [38] examine travellers' use of social media for travel information searches and find that perceived value (information reliability, enjoyment) and perceived effort influence users' adoption of social media. However, only the aspect of enjoyment directly affected social media usage.

Wang et al. [40] approach the topic from a tourist perspective and identify key evaluation factors for smart tourist attractions, including "smart information system", "intelligent tourism management", "smart sightseeing", "e-commerce system", "smart safety", "intelligent traffic", "smart forecasting" and "virtual tourist attractions". By understanding these factors, appropriate smart tourism devices and services can be offered to cate to tourists' preferences at the right time.

Regarding the identified knowledge gaps, it is important to address the usability limitations of mobile devices in smart tourism to provide information in a direct and intuitive manner. Furthermore, future research should consider incorporating cognitive and affective factors to examine decision-making processes in travel information searches.

### 3.3.7. Smart mobility

The smart mobility domain has been extensively explored within the field of smart city research [22]. In their comprehensive review of smart mobility technologies, Francini et al. [43] identify seven distinct clusters of research (1) Computing for urban safety and efficiency, (2) Solutions for reducing energy consumption and pollution, (3) Sensors and advanced digital technologies to support mobility management, (4) Sharing systems to address human mobility demands, (5) Sustainable planning for high-quality services, (6) Simulation and modelling for monitor mobility, and (7) Accessibility and connectivity of transport networks. [see also 22, for their review focusing on big data research].

Furthermore, Francini et al. [43] highlights various factors influencing the adoption of smart technologies, including technological innovations, environmental sustainability considerations, user satisfaction, and the physical characteristics of infrastructure systems. Conversely, Hasan et al. [45], in their review study on artificially intelligent transport systems, outline several barriers to the adoption of smart mobility technologies, including technological uncertainties, regulatory gaps, stakeholder unawareness, privacy and security concerns, and a lack of pilot studies.

There is a need for more validation and evaluation research in the areas of smart transportation and smart environment [22] Also, there is a lack of empirical research investigating stakeholder engagement and the different roles in logistics and transport systems [44,45] Another knowledge gap is simulations and modelling of real-world empirical data, forming the basis for assessing different smart technology implementations in logistics and transport [44,45].

### 3.3.8. Smart energy

Smart energy technologies encompass a range of technological solutions that aim to enhance energy efficiency, grid management, renewable energy integration, and energy consumption monitoring.

In the context of big data technology in smart cities, Brohi et al. [22] highlight smart energy as a sub-domains wherein Big Data Technology (BDT) is employed. Their literature review identifies key focus areas of research in BDT in the smart energy domain: i) BDT as an architecture for optimising energy and processing of sensor data efficiently, ii) policies for intelligent energy and transportation network in cities, iii) hybrid navigation systems based on open data, augmented reality, and big data application, iv) big data in large-scale intelligent smart city installation, and v) a multifaceted approach to smart energy utilising big data analytics [22]. In their study on the role of users' values in technology acceptance and adoption, Milchram et al. [41] find that while environmental sustainability positively impacts users' acceptance of smart grids, concerns regarding privacy, security and health can negatively influence user acceptance.

In terms of knowledge gaps, Brohi et al. [22] highlights that, compared to domains such as smart mobility, data application in the smart energy domain remains underdeveloped, calling for further exploration of prescriptive analytics and its application in smart energy systems. Akhatova et al. [42] examines the utilisation of agent-based modelling, a modelling technique used in energy system analysis, specifically focusing on building-related energy systems within urban districts. They emphasise the need to expand research to multi-level decision-making and stakeholder interactions within these systems [42]. Additionally, there is a need for more research supporting customers in adopting new technologies [41,42]. The relationship between values and user adoption is not always straightforward, highlighting the importance of studies that contribute to a more nuanced understanding if this relationship [41]. Akhatova et al. [42] stress the significance of comprehending the complexity of stakeholders, decision-making processes, and interactions in smart energy systems to overcome barriers and facilitate the transition towards new, smart, and decentralised energy systems.

### 3.3.9. Analysis of knowledge gaps

Based on the reviewed literature discussed above, seven categories of knowledge gaps have been identified. These are presented in Table 4 below. Further, Fig. 5 illustrates the distribution of knowledge gaps across each of the smart technology domains.

This analysis shows that knowledge gaps related to methodology and research approaches are most frequent, and relatively equally distributed across the smart technology domains. The second most frequent knowledge gap category is related to policy, governance, and smart domain implementations. This knowledge gap, however, is not distributed across all domains but rather concentrated on the domains of smart city and smart governance, while also mentioned in smart energy and smart mobility literature. Furthermore, being particularly relevant for this study, are the knowledge gaps related to the smart community domain. These are methodological and research approaches, digital integration, domain specific insights, and the social implications of smart technology implementation.

In the following, this paper will discuss how a sociotechnical perspective can contribute to addressing the identified knowledge gaps, thus contributing to advancing the research on smart technology implementation in the future.

## 4. Discussion

The goal of the work here is to, on the background of insights from smart technology domain research, to inform research on smart rural communities. The research questions formulated were: what are the

**Table 4**
Identified knowledge gaps in smart technology domains.

| Knowledge gap | Description |
|---|---|
| Policy, Governance, and Smart domain Implementation | The intersection of technology and urban policies remains underexplored. Digital citizen engagement and its implications for sustainability also require more insight. |
| Data, Technology, and System Challenges | The availability of real-world datasets and effectiveness of emerging technologies pose challenges. Additionally, scaling and integration of systems in real-world settings remain a concern. |
| Behavioural Dynamics and Decision-making | Transition from traditional to smart systems involves intricate human decisions, often underrepresented in current models. Understanding cognitive and moral values in tech acceptance is crucial. |
| Methodological Concerns and Research Approaches | Current research lacks robust and holistic methods. Furthermore, standardised metrics and longitudinal research designs to adequately evaluate smart domain advancements are not in place. |
| Digital Integration, Co-evolution, and Impacts | The broader societal implications of rapid digital transformations, how digital innovations co-evolve with societal norms, and the actual impact of technologies on social relations, are not well-understood. |
| Domain-Specific Technical Insights | As new technologies emerge, the standards and methods for their effective implementation remain a challenge. Another challenge is tailoring IoT development for specific situations or projects. |
| Digital Divide and Societal Implications | There is a need to research more on the (unintended) consequences of smart domain initiatives, addressing aspects such as digital divides, inclusiveness, and accessibility. |

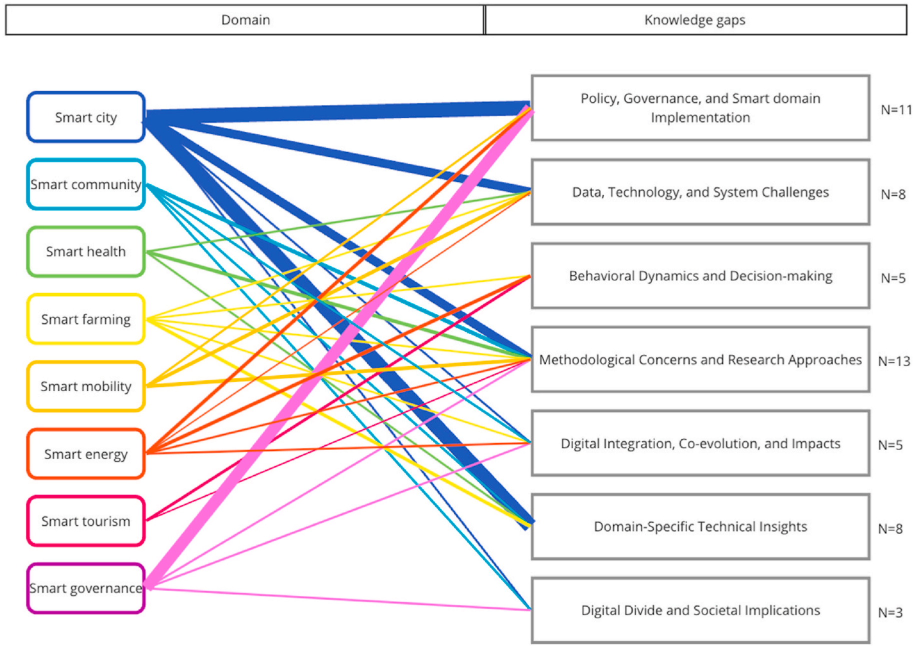


**Fig. 5.** Mapping of knowledge gaps to each smart technology application domain. N marks the number of papers referring to each knowledge gap category respectively. The line width indicates the number of papers from a research domain that refers to each knowledge gap category.

main findings and knowledge gaps of the existing literature on smart technology domains (RQ1); what implications does the sociotechnical perspective have for the study of smart technology domains? (RQ2), and; how can the sociotechnical perspective contribute to advancing research on smart rural communities? (RQ3). To investigate these research questions, a literature review was conducted combining an umbrella review with a supplementary review of literature in domains where there were no systematic literature reviews.

The findings section presents, analyses, and summarises the main findings and knowledge gaps seeking to answer RQ1. In so doing, objectives and research questions are categorised (see section 3.1), the main technologies are categorised and mapped to domains (section 3.2), key findings and knowledge gaps for each domain is presented (section 3.3.1-3.3.8). Crucially, the study presented an analysis which identifies seven knowledge gaps which are derived from knowledge gaps in individual domains, explain them, and point to which domains they relate to (see section 3.3.9).

In the following, to answer research questions two and three, contributions to research on smart rural communities are made by discussing the above findings using a sociotechnical lens. A sociotechnical consideration of the reviewed smart technology domain research is provided (section 4.1), implications for research on smart rural communities are discussed (section 4.2), and practical implications are drawn (section 4.3). Implications for practical policy in the smart rural community domain are also provided based on the discussion.

### *4.1. Considering smart domains in a sociotechnical perspective*

#### *4.1.1. Varying maturity in smart domains research*

This umbrella review showed that there is a difference in the maturity in domains. When reviews are conducted, this is an indication that there is a certain amount of literature on a topic. Using the number of systematic literature reviews as a measurement unit (see Table 2), smart city is the most studied domain with ten reviews, followed by smart energy and mobility. Some domains, like smart communities and tourism had no included reviews. Additionally, based on the number of results provided by the search strings in the databases Scopus and Web of science, the research fields of smart city, smart energy, and smart mobility have a higher maturity level, in terms of giving a significantly higher number of results than the other domains. This is also pointed out by Brohi et al. [22].

It is worth noting that the underexplored domains are perhaps the most relevant to the rural context. For smart farming for example, its' relevance to rural is given by the industrial presence of primary industries such as agriculture, as well as kindred industries such as forestry and fisheries. Smart health is also relevant given the demographics y in rural areas, combined with a lack of access to services. The health sector is an important employer in rural areas as well. As the tourism industry is increasingly manifesting itself as an important future-oriented industry for the periphery, smart tourism will also be a particularly interesting domain for rural communities.

Thus, there is a need for reviews in the domains with few or none reviews, for 1) to get an overview of the knowledge in those domains, and relatedly, 2) for rural areas to gain from this research.

#### *4.1.2. Need for focus on empirical studies of technologies in use*

From the screening of the review studies, an observation was that several initially interesting research contributions were excluded from the sample based on their reference to the term "review" in the sense of conducting a "theoretical and conceptual review" [see e.g., 52], reviewing specific technologies [see e.g., 53] or specific aspects of technology [see e.g., 54]. These studies were not reviewing empirical research, meaning there was no consideration of the observable effects of implementing smart technologies in domains. The implication of this is that there is ample room for more literature reviews on empirical research on implementations of smart technologies in communities. This is supported by the reviewed literature which also highlights the need for more extensive focus on empirical studies, calling for more publicly available data and real-world studies to validate effects of smart technology implementations [24].

A similar phenomenon was found in the search on supplementary literature. In the screening of the studies, several studies were excluded due to lack of focus on technology. These studies discuss smart domain issues related to aspects like sustainability, local development [55,56] or at a conceptual level [2], thus lacking an empirical consideration of technology in the study. Other studies had the opposite angle, a theoretical focus only on citizen or user adoption of smart implementations [57], neglecting the technological aspect. This suggests that there is ample room for studies taking a sociotechnical focus in their empirical studies, meaning that they are both specific on the technologies under investigation and considering how they interact with users in smart communities or domains [3,4].

In such a sociotechnical vein, studies have highlighted the need for more research focus on the potential downsides of smart technology projects, unintended consequences of the implementation of smart technology [48], and even the failure of such projects [21]. This knowledge gap, biasing research towards the one-sided focus on positive consequences and opportunities, represents a missed opportunity to consolidate knowledge about barriers and success factors for the implementation and use of smart technology: First, to gain a comprehensive understanding of the impacts and implications of the smart technology application in rural communities, it is crucial to examine both positive and negative aspects. By exploring the potential downsides and unintended consequences, researchers can provide a more balanced and holistic assessment of smart technology implementations. Second, identifying the risks and challenges associated with smart technology projects is essential for mitigating potential negative effects. Understanding the unintended consequences can help policymakers, community leaders, and technology developers anticipate and address issues, thereby minimising harm and optimising the benefits of these projects. Third, researching the failure and shortcomings of smart technology initiatives is crucial for promoting responsible deployment. By examining the reasons behind unsuccessful projects, researchers can identify critical factors that contribute to failure. This knowledge can guide future initiatives to ensure more effective and successful implementations. Forth, smart technology projects have social implications that extend beyond technological aspects. It is essential to investigate how these projects impact social dynamics, power structures, and community relationships. Understanding potential negative consequences, such as exclusion, inequality, or privacy concerns, is crucial for fostering equitable and inclusive smart rural communities. Lastly, by studying failed or challenging smart technology projects, valuable lessons can be learned. Researchers can identify common pitfalls, best practices, and strategies for overcoming obstacles. Sharing these insights can inform future projects and contribute to the development of guidelines, policies and frameworks that support successful implementation.

#### *4.1.3. A research field of fuzzy concepts*

Research on smart domains suffers from fuzzy concepts. Dashkevych and Portnov [27] found that there are more than 40 definitions. Other umbrella reviews have made similar findings:

> "Smart cities are a fuzzy and evolving concept. No universal definition can be made due to its different academic departures. In addition, smart city as a concept is evolutionary in nature dated back from urban planning platform addressing urbanization in the 90's. The conceptualization swings from digital solution to sustainability issue with technology, policy and communities lay in the central tenet of smart cities. Literatures have also underlined smart cities not only deliver positive outcomes but also negative impacts." [58].

Our review of the literature outside the smart city domains supports these findings. To support building a trajectory or a coherent field of study, authors should be specific on their concepts (e.g., technology, unit of analysis, contexts). Implications of this is that authors should define what they mean by a certain smart domain, be specific on the technology used, and on the unit of analysis in which a smart technology is developed and used.

Relatedly, the reviewed literature calls for an increased sensitivity towards the richness and complexity within different domains, through more thorough definitions and descriptions of the domain in question. In line with the sociotechnical perspective, the presence of multi-stakeholder networks, diverse contextual levels, and intricate interactions among stakeholders, as well as between human stakeholders and technological services and artefacts, necessitates further research to enhance the understanding of these relationships. Therefore, there is a need for research to delve into the complexities of these interactions and shed light on the dynamics and implications they entail [37,41,42].

#### *4.1.4. Ambiguous handling of the technical aspects*

An observation from the findings is that the descriptions of the technologies that are being studied are ambiguous. There is a lack of, or inadequate, definitions or descriptions of technologies (see Table 7). Studies often provide only a generic presentation of the technologies in question. There are ambiguous terminologies, and studies use terms having different meanings in describing the technologies. Some noteworthy efforts have been made, exemplified by the work of e.g., Ahmed et al. [59] with their "IoT based Smart Environment Taxonomy". Nevertheless, there remains a need to develop taxonomies encompassing both specific technologies and higher-level classifications.

This handling of technologies is problematic, especially in a sociotechnical perspective, as it does not take seriously the importance of the *technical* aspects of a sociotechnical relationship [60]. This challenge is also highlighted in the reviewed literature, as authors calls for ontological or conceptual discussion of the characteristics of a) specific technologies [25,29,44], b) smart technology (sub)domains [27,29] or c) technology innovation ecosystems [28].

As the sociotechnical perspective emphasises the importance of considering both the social and technical aspects of design, implementation, and utilisation of technology, one must be clear about the technical artefact or system under inquiry. This includes, e.g., the actual artefact (kind of technology), specific functionalities, design features, operational characteristics, affordances etc., and how these in turn shape and influence the interaction between technologies, and users, as well as the broader social context. An implication of this is the necessity to be specific about the technology being used and/or investigated. To support this process, research has suggested guidelines for categorisation of smart objects and underlying technology [61].

#### *4.1.5. A call for understanding social context*

A finding from this study, is that several authors state that the research on smart technology implementations and use has potential to be more explicit on the context or the domains in question [see e.g., 23, 26,32,33,35]. Other studies, have made similar findings, suggesting that "insights from humanity and social science may enrich the smart city research landscape" [58, p. 39]. Several studies call for a more holistic, interdisciplinary approach. It has been argued that the smart domain research, smart city in particular, tend to focus on the economic benefits of smart technology implementations, giving less focus to aspects of community, quality of services, or social and environmental aspects of sustainability [see e.g., 62]. Scholars have consequently criticised the smart city research field and practice for being technology deterministic and techno-centric, focusing too little on stakeholder involvement and citizen participation [7].

Learning from these insights, the implementation of smart technology must be fitted to the social, cultural, and environmental circumstances locally [6]. For smart technology initiatives to be efficient and effectful, that is, to ensure sustainability, appropriation, and effectiveness of new solutions in the long term, the process must start, be adapted and led by people and their needs [12]. Thus, it is important to develop knowledge on the societal and individual user aspects of smart technology implementation and use.

#### *4.1.6. The concept of smart rural communities in need for attention*

This literature review found no review studies of smart community focusing on empirical studies. The umbrella review literature search for review papers covering empirical studies within the domain of smart communities gave no results in either database. This finding might be ascribed to the search string applied for the umbrella review, requiring studies to be both review studies and covering an empirical perspective and could thus be a result of a limitation of the research design. However, while the supplementary literature search gave 23 and 14 results in respectively Scopus and Web of science, the corresponding result for the smart city domain was equivalent to respectively 898 and 822 results in the databases. This illustrates the gap in research focus between the smart city and smart community domains. That is, the smart city concept has been a popular research field in recent years, thus it is not unexpected that this is a more mature research field.

There are areas holding a transfer value from an urban to a rural perspective. One as such is privacy and security for that can be just as relevant regardless of domain (see e.g., Refs. [30,41,45]). In sum however, the mere numeric difference in contributions illustrates that there is a gap in the amount of research in the smart rural community domain, indicating a need for more research on studies of the smart community domain. Thus, this study goes a long way in confirming the presence of an urban bias in smart technology implementation and research.

#### 4.1.7. *Taking the user and technology developer seriously*

Further, research should be specific on which user group, organisation or region that is investigated and seek to explain how technology works in the unit of analysis. This requirement is evident in various domains [32,33,44–46,48]. Such specificity would contribute to leveraged context-sensitivity, which is called for in several studies (see e.g., Ref. [33]). Relatedly, the research in the reviewed domains also provides valuable guidance on how one can achieve this context-specificity, e.g., related to incorporation of the user perspective. Users' values, needs, roles should be embedded into the design and implementation of technological services and artefacts [38,39,41]. This is attuned to the sociotechnical perspective on implementation and adoption of technology. Further, research should emphasise the specific roles of users (see e.g., Refs. [26,32]) and technology providers (see e.g., Ref. [44]) in technology development. From a sociotechnical perspective, focusing on these aspects will provide deeper insights into how users contribute to the development and refinement of technologies, and the implications of their involvement in shaping innovative solutions [7]. It is crucial to address this knowledge gap in order to enhance the understanding of the collaborative dynamics between users and technology developers, ultimately leading to more effective and user-centred technology design and implementation.

#### 4.1.8. *Sustainability in smart technology implementation and use*

Furthermore, sustainability is of particular relevance to smart rural communities, and warrants greater attention in research. In example, Dashkevych and Portnov [27] highlights a concerning gap in the literature, with less than 2% of studies focusing on crucial components of sustainable urban development, such as renewable energy resources, urban waste and recycling, and green space expansions. This discrepancy contrasts with the recognised need, identified across several of the domains in this inquiry, to investigate the relationship between e.g., smart cities and climate change [20], as well as the effects of smart government initiatives in sustainability aspects on urban contexts [23]. Further, findings from smart farming research points to a need for research on more precise climate prediction in agricultural production [36]. Accurate climate predictions can greatly contribute to sustainable practices in agriculture, enabling farmers to make informed decisions that optimise resource utilisation and minimise environmental impact. Additionally, findings from a study on smart energy grids have demonstrated that environmental sustainability aspects positively influence users' technology acceptance [41]. That is, smart technologies have the potential to promote sustainability by e.g., reducing pollutant emissions [45], and fostering the adoption of environmentally friendly practises,.

It is evident that a strong connection exists between smart technology implementation and use, and sustainability aspects. However, to address the specific challenges and opportunities of communities, a more coherent and comprehensive research focus on sustainability is needed. From a sociotechnical perspective, the emphasis on sustainability in research on smart technology implementation in rural communities aligns with the community-centred approach advocated for sustainable living in these areas [6]. It underscores the importance of understanding the social, cultural, economic, and infrastructural aspects of communities and integrating them into technological solutions.

#### 4.1.9. *Contributions of a sociotechnical lens to knowledge gaps*

Relating back the knowledge gap categories presented in Table 4, the discussion above signifies several ways in which the sociotechnical lens can contribute to addressing them. Summarising the discussion, Table 5 shows how the sociotechnical perspective can contribute to addressing the identified knowledge gaps.

The different contributions are not strictly related to one single knowledge gap or another but interconnected across different knowledge gaps and sociotechnical analytic tools. In sum, adopting a sociotechnical perspective push smart technology research towards a more solid grounding in the actual and complex realities of human communities. This is needed in smart rural communities, as is discussed next.

**Table 5**
Sociotechnical contributions in addressing knowledge gaps in smart domain research.

| Knowledge gaps | Contribution of sociotechnical perspective |
|---|---|
| Policy, Governance, and Smart domain Implementation | - Discuss necessary policy development for rapidly evolving technologies and their societal implications, ensuring that governance mechanism align with technological capabilities and human needs [section 4.1.1, 4.1.5] |
| Data, Technology, and System Challenges | - Suggesting how to be concrete on smart technology [section 4.1.4]<br>- Facilitate empirical inquiries capturing both the specificity of the technical aspects, and the relation to the users [section 4.1.2] |
| Behavioural Dynamics and Decision-making | - Understand behavioural aspects of technology adoption and understanding how socio-cultural influences user decisions [section 4.1.7]<br>- Create theoretical models accounting for broader societal contexts of technology implementation [section 4.1.5] |
| Methodological Concerns and Research Approaches | - Emphasise the importance of holistic research designs, tracking technology impacts over time, within societal contexts [section 4.1.5]<br>- Studies evaluating failed or challenging smart technology projects can provide insights on pitfalls, best practices, and strategies when designing future smart technology implementation projects (optimising success of these projects) [section 4.1.1.] |
| Digital Integration, Co-evolution, and Impacts | - Capture the co-evolution of society and technology, seek insights on how technological change drive societal shifts, and vice versa [section 4.1.5] |
| Domain-Specific Technical Insights | - Highlight the importance of understanding the local practices and social contexts within which specific technologies operate [section 4.1.5.].<br>- Provide context-sensitive knowledge on domains particularly relevant for the rural context [section 4.1.1]<br>- Appreciate the richness and complexity of the different smart technology domains [section 4.1.3] |
| Digital Divide and Societal Implications | - Address societal inequalities that arise due to technological advancements. Guide research on how technologies can be designed and modified to be more inclusive and accessible, ensuring that technology do not enhance existing societal divides [section 4.1.1].<br>- Mitigate urban bias of smart city research, enabling deeper insights of barriers and success factors for implementation and use of technology [section 4.1.2] |

### 4.2. The relevance of smart technology domain research for rural contexts

#### 4.2.1. From silos to interconnectedness

While the smart city concept is primarily associated with urban areas, there are insights that can be extrapolated to the rural context. Particularly considering the interconnectedness between urban and rural regions, and the potential for technology bridging the urban-rural divide [7]. The cross-sectoral parts of smart city research are relevant to rural communities as it recognizes the interconnectedness of various domains. For instance, studies exploring the connection between smart city and sustainability [see e.g., 22,23,27,29] emphasise the importance of integrating environmental and ecological sustainability considerations in smart city research. This is equally applicable to rural communities, where sustainable practices and environmental preservation are crucial for maintaining the rural landscape, support agriculture and preserving natural resources. In the following sections, insights from research in various smart domains to smart rural communities are considered, with an emphasis on the need for a sociotechnical approach.

#### 4.2.2. The potential of smart technology for rural areas

Smart technologies, as shown in this paper, hold many promises to remedy some of these challenges. From smart communities, although the reviewed literature primarily focuses on smart communities in an urban context, aspects like the importance of technology as a tool for interaction, information sharing, and decision-making can be extended to rural communities [see e.g., 31]. From smart governance, technologies have the potential to provide access to information, public records, and government policies. Open data initiatives, digital portals, and online dashboards can enhance transparency, accountability, and citizen-government interaction [46,48]. From smart health, through teleconsultations, remote monitoring and digital health platforms, rural residents can receive timely medical advice, access specialist consultations, and manage their health conditions more effectively [32,33]. For smart farming, smart technologies such as precision farming, remote sensing and data analytics is highlighted with the potential of enhancing agricultural productivity. E.g., precision agriculture, with the emphasis on using digital technologies for increased farm management precision, holds significant potential for rural communities [35,37]. For smart tourism, technologies can enable rural destinations to develop unique and personalized branding strategies. By leveraging digital platforms, social media, and immersive technologies, rural communities can create compelling narratives, highlight their distinctiveness, and differentiate themselves from mainstream tourist destinations [38,39,63]. For smart mobility, remote monitoring systems can be employed to track the conditions of rural infrastructure, enabling timely maintenance, and ensuring safe transportation. Relatedly, application of smart traffic management systems can help optimise rural road networks and improve traffic flow [43,45]. Smart energy technologies, like microgrids and renewable energy systems, can play a role in providing clean and affordable energy to rural areas, as these technologies can enable decentralised energy generation, reducing the dependency on centralised grid infrastructure and enhance energy assess in remote areas [64].

#### 4.2.3. Context-sensitive smart technology implementations

As shown in the above discussion of knowledge gaps, the potential of smart technologies may be just that, an unrealised potential. Considering successful implementation from a sociotechnical perspective, several factors become relevant. First, smart technology implementations, and the research on smart technology domains, need to be context specific. Within a sociotechnical perspective, it would be important to consider the particularities of rural users and practices [4]. Consider for example how a ride sharing service (such as Uber) has a greater potential in cities than in rural areas. In a rural context, building digital ecosystems can enable effective communication, coordination, and knowledge exchange among different actors such as farmers, local businesses, community organisations, and government agencies. Another example is smart tourism. As for the smart tourism domain, adoption, and implementation of smart tourism technologies in rural communities face specific challenges. These include limited access to technology infrastructure, digital literacy barriers, and the need for capacity-building and training programs for community members [51]. Additionally, issues related to data privacy, cultural authenticity and balancing technology use with the preservation of the rural character and heritage in a way that mitigate the erosion of local tradition and authenticity, should be carefully addressed [65]. A third example of adapting to specific contexts is smart energy. Successful implementation of smart energy technologies in rural communities requires addressing context-specific challenges, including technological, economic, and social factors. Aspects such as affordability, local capacity building, community engagement, and policy support play significant roles in realising the potential benefits of smart energy technologies in rural contexts [66].

Second, technological determinism should not be assumed. Change does not necessarily follow from technology alone. For smart governance in rural areas, similar to cities [23], this can easily end up as an unrealised potential. As alluded to in the introduction, a deterministic perspective would assume that simply bringing the technology into a context would have the social institutions adapt. Rather, a sociotechnical perspective would argue that technologies are underdetermined by technical criteria alone [67]. What this means in practice is that there is generally a surplus of workable solutions, and social actors make the final decision among a wide array of viable options. This means, that even though the smart governance technologies are available, there is no guarantee they are used to improve governance. Achieving this would require engagement, that is, both government and citizens choosing to actively engage with and use technological options. Only then would a smart technology implementation enhance democratic processes, foster social inclusion, and address the specific needs and aspirations of rural communities.

Third, a sociotechnical perspective necessitates the involvement of users. In example, while the implementation of smart health technologies in rural communities can bring significant benefits, it is important to address the underlying challenges of internet connectivity, infrastructure, digital literacy, cultural acceptance, and privacy concerns. From a sociotechnical perspective, successful implementation encompasses an emphasis on the need to involve local stakeholders, consider community needs, and ensure the integration of these technologies into the existing rural healthcare ecosystems [7]. To succeed, studies would need to be conducted within rural settings, focusing on data from individual and organisational perspectives [32,33], and utilising real-world data [34]. Another example of involvement is, in smart farming, the adoption of smart farming technologies in rural areas require sustained investments in technical training and policies that incentivise adoption [35]. This is in line with the sociotechnical emphasis on the importance of understanding the social and organisational factors that influence technology adoption. Factors such as access to technology, affordability and the availability of support infrastructure play a crucial role in facilitating the adoption and effective utilisation of smart farming technologies in rural contexts.

Forth, a sociotechnical perspective would require a consideration of specific rural values. Consider smart mobility, for example. It is essential to acknowledge the potential drawbacks and challenges of the adoption of smart mobility technologies in rural areas. For example, limited infrastructure and connectivity holds the potential for exacerbating existing disparities between urban and rural areas, potentially leading to unequal access to these technologies [68]. Furthermore, the implementation of smart mobility technologies can potentially disrupt traditional rural transportation services, which in term can have economic implications in terms of e.g., job losses, thus challenging the social sustainability of rural areas. A sociotechnical perspective acknowledges that technology comes with certain built-in values [67]. Researchers, policymakers, and technology providers should be aware of the potential built-in urban bias [see e.g., 69,70] in existing technologies.

Mitigating such bias and fitting to rural needs would be necessary for the sustainable and inclusive development of smart mobile solutions in rural areas.

### 4.3. Practical implications for policymakers and technology providers

As discussed above, there is potential for the development of rural areas by adopting smart technology. However, successful implementation of such technologies does, as accounted for above, require a greater degree of context-sensitivity than can be derived from research initiatives to date. To be successful, the rural context must be given due attention.

Rural areas face often specific characteristics and needs that differ from urban areas, and their perspectives and challenges must be considered to ensure successful adoption and impact of technology: For one, rural areas face several infrastructural limitations such as limited internet connectivity, unreliable power supply or inadequate technology infrastructure [71]. Further, these areas face challenges in accessing quality healthcare services due to geographic distances and limited healthcare infrastructure [72]. Other challenges, like accessing public services and resource efficiency, i.e., due to low concentration of the population, long distances, and/or poor connectivity to regional power centres, can also be mentioned [1]. These constraints must be acknowledged and addressed to ensure that the technology implementation is feasible and sustainable in rural environments. Technology implementation in rural communities should consider the social, cultural, and economic aspects of these contexts. Researchers have emphasised the importance of understanding the local needs, values and practices to ensure that technology solutions align with the community's goals and priorities [73].

#### 4.3.1. Overcoming the urban bias

The findings of this study indicate the presence of an urban bias in the smart technology domain research. The urban bias refers to the phenomenon where technology development and deployment predominantly focus on urban areas, thus, often neglecting the needs and realities of rural communities [69]. This bias can have significant implications on several aspects. One is differential access and inequality. The urban bias in smart technology exacerbates existing inequalities by further marginalising rural communities. Smart city initiatives tend to concentrate resources, infrastructure, and technological innovation in urban areas, leading to and even amplifying the digital divide between urban and rural populations [70].

Another aspect is technology appropriateness. Off-the-shelf technology solutions are often designed for urban contexts and may fault to address the specific challenges and requirements for rural communities. The implementation of smart technology designed for urban contexts may not be suitable or effective in rural areas. As discussed, rural communities often have different needs, resource constraints, and social structures, which require technology solutions tailored to their specific contexts. Ignoring these differences can lead to technology implementations that are incompatible, underutilised, or even harmful [74]. Adapting the technologies to the local contexts are necessary to ensure their relevance and effectiveness in rural settings.

Relatedly, research has advocated for the need for inclusive and participatory governance frameworks that consider the needs and perspectives of rural communities [75]. Participatory approaches can empower rural community members, enhance the relevance, acceptance and effectiveness of the technology, and lead to more sustainable outcomes of the technology implementations [76]. Thus, considering the sociotechnical perspective, engaging rural communities in the decision-making process, involving them in co-design and incorporating their feedback is crucial.

Further, smart technology implementation should align with the principles of sustainable development (see e.g., Ref. [77]). Neglecting rural communities in the process can hinder efforts to achieve sustainable and inclusive development. Research suggest that a balanced and equitable approach to smart technology implementation is vital to address social, economic and environmental challenges in both urban and rural contexts [78]. Addressing the urban bias requires a shift towards more inclusive, context-sensitive approaches that consider the needs, aspirations, and socio-economic realities of rural communities. By doing so, smart technologies can contribute to bridging the urban-rural divide and promote more equitable and sustainable development.

#### 4.3.2. Policy implications safeguarding rural interests

Based in the sociotechnical perspective policy implications comprise the need for a holistic and inclusive approach to the implementation of smart technologies in rural areas. Policy frameworks should promote participatory approaches in technology implementation, encouraging the active engagements of rural communities. This can be achieved through mechanisms such as participatory design, co-creation, and inclusive decision-making processes [7]. Policies can facilitate the involvement of rural stakeholders in sharping technology projects, ensuring their voices are heard and their needs are considered.

Further, policymakers should work to ensure that sufficient financial resources are allocated to support smart technology initiatives in rural areas. Funding mechanisms should be designed to address the resource constraints faced by rural communities. This can include grants, subsidies, and targeted funding programs that specifically cater to the unique needs and challenges of rural areas.

Lastly, policies should encourage and facilitate collaboration and knowledge and practice sharing between stakeholders, including government agencies, researchers, technology providers, and rural communities. This can foster learning, exchange of best practices, and innovation in smart technology implementation. Platforms for sharing experiences and lessons learned can support evidence-based policymaking and facilitate continuous improvement in technology interventions. By addressing these aspects, promoting participation, and tailoring solutions to local contexts, policymakers can create an enabling environment for the successful adoption and utilisation of smart technologies in rural areas.

### 4.4. Limitations

As detailed in section 3.3.2, the umbrella review literature search did not yield any results of review studies of smart community covering empirical studies. In addition, relevant studies in the supplementary literature were limited. This limitation can be attributed to the search string employed during the literature searches, which specifically required studies to have an empirical focus. There is relevant research conducted on this topic that was not captured by the search string. Here, e.g., the journal *Sustainability,* and its special issue "Sustainable Smart Cities and Smart Villages Research" from 2018, could be mentioned. Furthermore, studies such as of Visvizi and Lytras [79] or Zavratnik [6] were not found in the search. Relevant studies emerge, such as on rural areas and tourism [80]. Another potential explanation for why these studies did not show up in the search is that these studies use terminology such as "digitalisation" or "digital transformation" rather than referring explicitly to "smart [domain]". The findings of this study are necessarily limited by the scope of the included papers and the criteria in the search strategy.

Relatedly, the limited research found on specifically on the smart community domain, might be the omission of the specific term "smart community" in papers' meta data. Consequently, these papers may not be indexed under the category of smart community in searchable databases, limiting their discoverability. Researchers should ensure the inclusion of relevant terms in the title, abstract, and/or keyword of their papers.

Acknowledging the above limitations, the work here sought to mitigate by incorporating multiple terms in the search string for each domain (see Table 6 in Appendix). The search string was also subjected to discussion and quality assessment in the wider research consortium, comprising experts across various domains. Nevertheless, future research could benefit from expanding the scope of this study to include more detailed exploration of specific smart domains, or incorporating other domains not covered in this study.

As detailed in the method section, the criterion of citation count was employed for the purpose of sorting and selecting papers reviewing the supplementary literature. This approach may favour older studies, potentially overlooking more recent and valuable scientific contributions.

## 5. Conclusion

This study has reviewed the literature on the following eight domains: *smart cities, smart community, smart health, smart farming, smart tourism, smart mobility, smart energy*, and *smart governance*. The aim was to provide insights from research in the smart domains to the field of smart rural communities. Compared to smart city research, the concept of smart rural communities is still rather underdeveloped. This study has focused on empirical research to avoid the technological determinisms reported from smart city research and to gain insights into how smart technology is used in domains.

Considering the research questions set for this inquiry, this study has revealed several challenges and research needs within the smart technology implementation field: Related to RQ1, asking for findings and knowledge gaps, the findings reveal several knowledge gaps within smart domain research. First, there is a lack of standardised definitions and frameworks for delineating domains, hindering clarity and consistency in research. Second, there is a need for increased specificity and sensitivity regarding the technical aspects of the smart technologies, ensuring a more detailed understanding of the technologies involved. Third, there is a need for research efforts to focus on the social, organisational, and cultural contexts in which technology implementations occur, including a heightened emphasis on the user perspective.

Related to RQ2, this study concludes that the sociotechnical perspective holds relevant implications for the research on smart technology domains: Looking beyond the need for research considering the social contexts in which technologies are implemented, the findings of this study highlight the need for research that explores the interconnectedness of technological and social factors, enabling a more comprehensive understanding of the dynamics that shape and are shaped by technology. Adopting a sociotechnical perspective promotes a holistic approach to studying smart technology domains, facilitating a deeper appreciation of the intricate interdependencies between technology and its social contexts. This can enable policymakers, researchers, and practitioners to actively develop smart technology solutions for rural communities that are both contextually appropriate and inclusive.

Finally, considering RQ3, this study concludes that the application of the sociotechnical perspective holds promise for advancing research on smart rural communities. The sociotechnical perspective emphasises the significance of considering specific challenges, opportunities and needs specific for the rural areas. By considering the rural perspective in technology implementation, it is possible to address the challenges and leverage the strengths of these communities, and design systems that are suitable and powerful. Further, adopting the sociotechnical perspective on the case of rural communities can contribute to shifting the research field way from the urban bias, towards a community-centred and context-sensitive approach. Applying this perspective enables researchers to gain a deeper understanding of the factors that contribute to the success and failure of smart technology implementations in rural communities. That is, in overcoming the normative and urban bias in smart technology research can pave the way for more efficient and tailored strategies for their development and deployment. Ultimately, this can contribute to bridging the digital divide between urban and rural areas, empower rural communities, and promote inclusive and sustainable development.

## Author statement

Kine Charlotte Jakobsen, MA: Conseptualizing, investigation, writing, review, editing. Marius Mikalsen, PhD: Writing, review, editing, supervision. Grethe Lilleng, MSc: Conseptualising, investigation, writing.

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used OpenAI's ChatGPT-4 in order to refine the language of the certain paragraphs of the text. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

## Data availability

Data will be made available on request.

## Acknowledgments

This study has been partially funded by the European Commission H2020 program, through the project AURORAL (Grant No.: 101016854). A special thanks to Tore Syversen and Bård Johan Hanssen for supporting the initial phases of the work, and providing valuable comments. Furthermore, a thanks to the anonymous reviewers and the editor for feedback and suggestions for improvements.

## Appendix

**Table 6**
Keywords used in the search strings for the smart domains.

| Domains | Search string keywords |
| --- | --- |
| Smart city | Smart city, smart cities |
| Smart community | Smart community, smart communities, smart village, smart rural |
| Smart health | Smart health, smart living, smart ageing, ambient assisted living |
| Smart farming | Smart farming, social farming, smart agriculture, digitalized farming |
| Smart tourism | Smart tourism, etourism, e-tourism |
| Smart mobility | Smart mobility, smart logistics, smart transport, intelligent transport |
| Smart energy | Smart energy, distributed energy, distributed generation, on-site generation, decentralised energy, district energy |
| Smart governance | Smart governance, smart government, e-governance, egovernance, electronic governance, smart public security, smart public service |

**Table 7**
Bibliographical data of sample papers.

| Authors | Domain | Title | Year | Journal |
|---|---|---|---|---|
| Abduljabbar et al. [29] | Smart City, Smart Energy | The role of micro-mobility in shaping sustainable cities: A systematic literature review | 2021 | Transportation Research Part D |
| Ahmadi-Assalemi et al. [24] | Smart City | Cyber Resilience and Incident Response in Smart Cities: A Systematic Literature Review | 2020 | Smart Cities |
| Akhatova et al. [42] | Smart Energy | Agent-Based Modelling of Urban District Energy System Decarbonization—A Systematic Literature Review. | 2022 | Energies |
| Bacciu et al. [34] | Smart Health | An experimental characterization of reservoir computing in ambient assisted living applications. | 2014 | Neural Comput & Applic |
| Bonsón et al. [46] | Smart Governance | Citizens' engagement on local governments' Facebook sites. An empirical analysis: The impact of different media and content types in Western Europe | 2015 | Government Information Quarterly |
| Brohi et al. [22] | Smart City, Smart Mobility, Smart Energy, Smart Governance | Big data in smart cities: a systematic mapping review | 2018 | Journal of Engineering Science and Technology |
| Caputo et al. [31] | Smart Community | Beyond the digital ecosystems view: Insights from Smart Communities | 2016 | 9th EuroMed Conference of the EuroMed Academy of Business |
| Carolan [37] | Smart Farming | 'Smart' Farming Techniques as Political Ontology: Access, Sovereignty and the Performance of Neoliberal and Not-So-Neoliberal Worlds. | 2018 | Sociologia Ruralis |
| Chung and Koo [38] | Smart Tourism | The use of social media in travel information search | 2015 | Telematics and Informatics |
| Dashkevych and Portnov [27] | Smart City | Criteria for Smart City Identification: A Systematic Literature Review | 2022 | Sustainability |
| Fahmideh and Zowghi [26] | Smart City | An exploration of IoT platform development | 2020 | Information Systems |
| Francini et al. [43] | Smart Mobility | Systematic Literature Review on Smart Mobility: A Framework for Future "Quantitative" Developments | 2021 | Journal of Planning Literature |
| Green et al. [35] | Smart Farming | A scoping review of the digital agricultural revolution and ecosystem services: implications for Canadian policy and research agendas | 2021 | Facets |
| Hasan et al. [45] | Smart Mobility | A review of the transformation of road transport systems: Are we ready for the next step in artificially intelligent sustainable transport? | 2020 | Applied System Innovation |
| Huang and Thomas [28] | Smart City | A review of the Living Lab research and methods for User involvement | 2021 | Technology Innovation Management Review |
| Huang-Lachmann [20] | Smart City | Systematic review of smart cities and climate change adaptation | 2019 | Sustainability Accounting, Management and Policy Journal |
| Jin et al. [36] | Smart Farming | Hybrid deep learning predictor for smart agriculture sensing based on empirical mode decomposition and gated recurrent unit group model. | 2020 | Sensors (Switzerland) |
| Khosrojerdi et al. [25] | Smart City | Integrating artificial intelligence and analytics in smart grids: a systematic literature review | 2020 | International Journal of Energy Sector Management |
| Latikka et al. [33] | Smart Heath | Older Adults' Loneliness, Social Isolation, and Physical Information and Communication Technology in the Era of Ambient Assisted Living: A Systematic Literature Review. | 2021 | Journal of Medical Internet Research |
| Lee et al. [30] | Smart Community | Privacy-preserving data analytics in cloud-based smart home with community hierarchy | 2017 | IEEE Transactions on Consumer Electronics |
| Lytras and Visvizi [2] | Smart Community | Who uses smart city services and what to make of it: Toward interdisciplinary smart cities research. | 2018 | Sustainability |
| Milchram et al. [41] | Smart Energy | Moral Values as Factors for Social Acceptance of Smart Grid Technologies. | 2018 | Sustainability |
| Noguera et al. [39] | Smart Tourism | A mobile 3D-GIS hybrid recommender system for tourism. | 2012 | Information Sciences |
| Perego et al. [44] | Smart Mobility | ICT for logistics and freight transportation: A literature review and research agenda | 2011 | International Journal of Physical Distribution and Logistics Management |
| Tomor et al. [23] | Smart City, Smart Governance | Smart Governance For Sustainable Cities: Findings from a Systematic Literature Review | 2019 | Journal of Urban Technology |
| Torres et al. [47] | Smart Governance | E-governance developments in European union cities: Reshaping government's relationship with citizens. | 2006 | Governance-An International Journal of Policy Administration and Institutions |
| Viale Pereira et al. [48] | Smart Governance | Increasing collaboration and participation in smart city governance: a cross-case analysis of smart city initiatives | 2017 | Information Technology for Development |
| Wang et al. [40] | Smart Tourism | How smart is your tourist attraction? Measuring tourist preferences of smart tourism attractions via a FCEM-AHP and IPA approach. | 2016 | Tourism Management |
| Zander et al. [32] | Smart Health | Implementation of welfare technology: a systematic review of barriers and facilitators | 2021 | Disability and Rehabilitation: Assistive Technology |
| Zhao et al. [21] | Smart City | Smart city research: A holistic and state-of-the-art literature review | 2021 | Cities |

**Table 8**
Review method, data material, and method of appraisal, in umbrella review sample literature.

| Authors | Review type | N studies reviewed | Publication date range | Type of studies reviewed | Appraisal method | Method of synthesis of evidence |
|---|---|---|---|---|---|---|
| Abduljabbar et al. [29] | Systematic literature review | 328 | 2000–2020 | Consolidates knowledge on the topic of micro-mobility as a transformative solution for meeting sustainability outcomes in urban environments. | | |
| Ahmadi-Assalemi et al. [24] | Systematic literature review | 52 | 2011–2019 | Empirical primary studies addressing cyber resilience and digital forensic incident response (DFIR) aspects of cyber-physical systems (CPSs) in smart cities. | | PICOC |
| Akhatova et al. [42] | Systematic literature review | 25 | N/A | Agent-based modelling in urban district (building-related) energy systems. | PRISMA | |
| Brohi et al. [22] | Systematic mapping review | 65 | 2013–2017 | Big data research contributions produced to assist smart cities in achieving sustainability goals. | | |
| Dashkevych and Portnov [27] | Systematic literature review | 51 | 2011–2019 | Recent empirical studies on the smart city phenomenon. | PRISMA | |
| Fahmideh and Zowghi [26] | Systematic literature review | 63 | 2008–2019 | Studies of IoT platform development. See Table 5 "Application domain of identified approaches". | Critical Appraisal Skills Programme | |
| Francini et al. [43] | Systematic literature review | 102 | 2007–2020 | Theoretical and empirical research on smart mobility, aiming to classify them into clusters. | | Cluster analysis |
| Green et al. [35] | Scoping review | 74 | N/A | Examines the scientific evidence of Digital agriculture technology (DATs) to reduce agriculture's negative impacts on ecosystem and increase agriculture's enhancement of ecosystem. | | Emergent coding |
| Hasan et al. [45] | Systematic mapping review | 99 | N/A | State-of-the-art research on AV and ITS transport systems, especially focusing on research methodologies in existing literature as well as their main findings and limitations. | | |
| Huang and Thomas [28] | Bibliometric analysis and literature review | 42 | 1991–2021<br>1991–2019 | Studies on Living lab. | | |
| Huang-Lachmann [20] | Systematic mapping review | 98 | 2006–2017 | Studies combining smart city and climate change adaption, i.e., green roofs, ICT, wastewater, energy, solid waste. | PRISMA | Content analysis |
| Khosrojerdi et al. [25] | Systematic literature review | 108 | 2010–2020 | Information system research and data analysis, concerning application of AI-based methods and data analytics in technical fields of power networks known as smart grids. A broad set of smart grid functionality is reviewed, focusing on commonalities among several applications (see "findings" in abstract for examples). | PRISMA | |
| Latikka et al. [33] | Systematic literature review | 23 | 2006–2021 | Empirical studies. | PRISMA | Content analysis |
| Milchram et al. [41] | Systematic literature review | 49 | 2009–2017 | Journal articles on smart grid, smart energy, smart metering, smart home, home energy management, energy and digitalisation, and smart technology. | | |
| Perego et al. [44] | Systematic literature review | 44 | 1994–2009 | Studies examining implementation of ICT logistic or transportation applications in a particular company and articles presenting wider research on the diffusion of ICT applications among logistics and freight transportation companies in different countries. | | |
| Tomor et al. [23] | Systematic literature review | 114 | 2006–2016 | Literature related to smart cities and smart governance: Case studies, questionnaires, experiments, literature review, comparative research | PRISMA | |
| Zander et al. [32] | Systematic review | 33 | 2007–2020 | Implementations of welfare technology for older people, people with disabilities and informal caregivers. | PRISMA | |
| Zhao et al. [21] | Systematic mapping review | 191 | 2000–2019 | Cases in different disciplinary areas: technology, management, entrepreneurship, urban government and planning, intellectual capital, transportation, supply chains, tourism, and more. | | Qualitative content analysis (Vaismoradi et al., 2016) |

**Table 9**
Method and data material, in supplementary literature.

| Authors | Methods and material |
|---|---|
| Bacciu et al. [34] | An experimental/empirical assessment of several distributed ESN configurations, based on realistic WSN-induced layouts, with application to user movement forecasting using real-world RSS (radio signal strength) data. |
| Bonsón et al. [46] | Case study with samples from 15-member countries of the EU via 75 local governments belonging to four different public administration styles, analysing 50 social media posts from each municipality. |
| Caputo et al. [31] | Literature review and analysis of the domain Smart communities. |
| Carolan [37] | 93 interviews with from four groups: (1) 24 employees from big data and/or precision farm equipment companies located in North America, the UK, Australia, and New Zealand; (2) 25 conventional farmers in USA who employ big data and precision agriculture; (3) 21 individuals from the USA associated with Right-to-Repair movement; and (4) 23 farmers from the US and the UK. |

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**Table 9** (*continued*)

| Authors | Methods and material |
|---|---|
| Chung and Koo [38] | Empirical data collected (n = 695) in a survey and run a structural equation modelling. And literature pertaining to the six constructs known as information reliability, enjoyment, complexity, perceived effort, perceived value, social media usage for travel information search. |
| Jin et al. [36] | Sensing data of an agricultural IoT system in Beijing. The data was obtained from 2016 to 2018 and consisted of 20,013 time series data points. Empirical mode decomposition (EMD) method is used to decompose the climate data into fixed component groups. |
| Lee et al. [30] | Empirical investigation/demonstration of smart home privacy protecting mechanisms. Data collected from smart home systems. |
| Lytras and Visvizi [2] | Pilot study survey with 102 responses from different target groups in 28 countries. |
| Noguera et al. [39] | Questionnaires and user testing. 27 testers, 19 males and 8 females, with ages ranging from 24 to 48 years, being 30 the average age. |
| Torres et al. [47] | Empirical survey of three e-government dimensions (e-service (n = 67), e-democracy (n = 60) and Web Maturity (WM) (n = 6)). |
| Viale Pereira et al. [48] | Case study, cross-case analysis of multiple cases. |
| Wang et al. [40] | Literature review, survey questionnaire (N = 409), factor-analysis. |

**Table 10**
Objective and research question.

| Reference | Objective | Research questions |
|---|---|---|
| Abduljabbar et al. [29] | Consolidates knowledge on micro-mobility, analyses past and on-going research developments, and provides future research directions by using SLR. | RQ1: What are the key topics reported in the scientific literature on micro-mobility, and how did the research on these topics evolve over time? RQ2: Which papers and authors have been most influential in shaping the development of the literature to date? RQ3: What is the current state of progress in the scientific literature in examining the impacts of micro-mobility as a sustainable mode of urban transport? RQ4: What are the main gaps in knowledge, barriers, and pathways to enable wide-spread deployment of micro-mobility solutions? RQ5: What are the future research directions and key questions to be answered in micro-mobility knowledge areas in future research? RQ6: Which research streams can be envisaged for micro-mobility as part of a sustainable low carbon mobility framework for future cities? |
| Ahmadi-Assalemi et al. [24] | Smart cities accelerated by Industry 4.0, including IoT and enhanced of the application of emerging innovative technologies, is growing rapidly. This can in turn create highly fragile and complex cyber-physical-natural ecosystems. | RQ1: How do existing frameworks and systems that address cyber-physical systems (CPSs) in smart cities support cyber resilience and what empirical evidence has been reported? RQ2: How do the identified frameworks and systems in smart cities address modern digital forensics and incident response (DFIR)? RQ3: What are the current cross-sector proposals or applications in smart cities that attempt to utilise interactions in CPSs for the purpose of improving DFIR? |
| Akhatova et al. [42] | Objective to provide an overview of how agent-based modelling has been used to model policy interventions that facilitate the decarbonization (i.e., energy transition) of building-related urban district energy systems and consider stakeholders' social characteristics and interactions. | RQ1: How has agent-based modelling been applied in studying the urban district (building-related) energy systems? |
| Bacciu et al. [34] | The study is a systematic experimental investigation of the RC (reservoir computing) approach jointly considering both the efficiency and the efficacy of proposed solution in a real-life AAL application. Further, the study specifically evaluates the trade-off between predictive accuracy and memory occupation cost, which is central to embed learning modules on low-power WSN devices. | N/A |
| Bonsón et al. [46] | The objective of the study was to measure the impact of media and content types on stakeholders' engagement on Western European local governments' Facebook pages. | RQ1: Does the use of different media and content type influence citizen engagement? Are there any communicational differences across different public administration styles? |
| Brohi et al. [22] | Big data technology (BDT) in Smart Cities (SC), and maturity level within research domain. | RQ1: How are BDTs being used in smart cities? RQ2: What is the publication-fora relating to big data in smart cities? RQ3: What is the maturity level of the research domain? RQ4: What types of analytics are being applied in smart cities? RQ5: What are the current state and future direction of big data research in smart cities? |
| Caputo et al. [31] | The paper aims to analyse the challenges of emerging Digital Ecosystems. The principal goal of this work is to enrich previous studies on the topic of Digital Ecosystem with possible contributions derived from the studies on Smart Communities. | RQ1: In which ways it is possible to improve the management of Digital Ecosystems adopting the logics of Smart Communities? RQ2: What are the real contributions of ICT in the emersion and in the functioning of Digital Ecosystems? |
| Carolan [37] | Investigation of how respondents negotiated technology, knowledge, information, and data, both discursively (by what they said) and performatively (by what they did and with whom). | N/A |
| Chung and Koo [38] | This paper examines the travel information searches using social media as a new search behaviour from a value perspective. | RQ1: Perceived value has a positive effect on the travel information searches in social media usage. RQ2: Information reliability has a positive effect on perceived value. RQ3: Information reliability has a positive effect on the travel information searches in social media usage. RQ4: Enjoyment has a positive effect on perceived value. RQ5: Enjoyment has a positive effect on the travel information searches in social media usage. |
| Dashkevych and Portnov [27] | Aims to bridge the knowledge gap by a systematic literature review of recent studies, in which various empirical criteria are used for smart city identification. Identifies metrics within three main categories: smart digital technology, living conditions, and environmental (ecological) sustainability. | N/A |
| Fahmideh and Zowghi [26] | IoT platform development as key enablers for smart cities initiatives. Reviews empirical findings, recommendations, and knowledge gaps. | RQ1: What is the current state of existing approaches for developing IoT platforms with respect to the proposed evaluation framework introduced in Section 2? RQ2: what is the application and type of these approaches? RQ3: |

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**Table 10** (*continued*)

| Reference | Objective | Research questions |
|---|---|---|
| | | How is IoT platform development process lifecycle perceived in the literature? RQ4: What roles are involved in the development of IoT platforms? RQ5: What modelling activities and modelling languages are used during IoT platform development? |
| Francini et al. [43] | The object of the study is the "Smart Sustainable Mobility" system as the synthesis of the concept of smart mobility and the sustainability goals in order to clarify its use and description by reviewing the international literature. The research goal is to reach an extended and shared definition of smart mobility using the cluster analysis. | RQ1: Which are the main lines of research on smart mobility? RQ2. Is it possible to give a definition of smart mobility that includes these aspects? |
| Green et al. [35] | Examine how digital agricultural technologies may enhance agriculture's support of ecosystem services. | RQ1: What scientific evidence supports claims that DATs can reduce agriculture's demand for ES as inputs? (Quadrant 1). RQ2: What scientific evidence supports claims that DATs allow agriculture to sustainably enhance or diversify regulation and maintenance ES? (Quadrant 2). RQ3: What scientific evidence supports claims that DATs reduce downstream, negative impacts on regulation and maintenance ES? (Quadrant 3) |
| Hasan et al. [45] | Study performs a critical review of peer-reviewed research in the field of vehicular automation, so as to map the status of autonomous urban transportation, and specifically to ask the question of how driverless vehicles are changing the way we think of artificially intelligent transportation systems. | RQ1: What is the current research on the artificially intelligent transportation system (ITS) and autonomous vehicles (AVs)? |
| Huang and Thomas [28] | This study investigates the progress of Living lab research over time. It explores its current trends, along with methods and tools used by Living labs for user involvement. | 1. How has living lab research advanced over time, and what are the current trends? 2. What are the methods and tools used by living labs for user involvement? |
| Huang-Lachmann [20] | Climate change and the importance of advancing climate change studies by better understanding the consequences of climate change policy. The outcomes of the smart city applications in climate change adaptation aim to contribute to the exploration of developing indicators for smart city studies in climate change. | RQ1: What smart cities approaches are applied in climate change adaptation in cities? RQ2: What are the benefits of smart cities applications in adaptation to climate change in cities? |
| Jin et al. [36] | This study focuses on medium-term prediction in an agricultural IoT system by processing the collected sensing data with artificial intelligence methods. Medium-term prediction means predicting 20 to 30 steps ahead. | N/A |
| Khosrojerdi et al. [25] | explore the latest approaches in integrating artificial intelligence and analytics (AIA) in energy smart grid projects. | RQ1: What is the growth trend in Smart Grid projects using intelligent systems and data analytics? RQ2: What business value is offered when AI-based methods are applied? RQ3: How do applications of intelligent systems combine with data analytics? RQ4: What lessons can be learned for Smart Grid and AIA projects? |
| Latikka et al. [33] | Aims to gain insight into how technology can help overcome loneliness and social isolation other than by fostering social communication with people and what the main open-ended challenges according to the reviewed studies are. | RQ1: What has been studied so far, from a sociotechnological perspective, in the field of loneliness and social isolation in older adults using physical ICT solutions? RQ2: How can physical ICT solutions help overcome the issues of loneliness and social isolation among older adults other than by fostering social communication with people? RQ3: What are the main open-ended challenges according to existing studies? |
| Lee et al. [30] | Smart community public housing projects involving tens of thousands of households have recently been implemented. This study proposed a privacy-preserving smart home system, which connects a single home controller with data-hiding capabilities through community networking and integrates the data to a hierarchical architecture on a cloud platform for a data analytical access control mechanism. | N/A |
| Lytras and Visvizi [2] | Sought to add empirical backing to the argument that smart cities research suffers from a 'normative bias', i.e., that the ICT-enhanced vision of what is technically possible does not always match the on-the-ground reality. | RQ1: Is it possible to establish links between different user profiles and their abilities to use certain clusters of smart city services/applications? RQ2: How does different users of smart city services/applications perceive them and the value that they add? RQ3: How important for smart city efficiency are questions and concerns about security, privacy, ethics, and others? RQ4: Which are the examples of good practices of smart city services based on associated and perceived value from users? RQ5: What are the perceptions of smart city users regarding the impacts of advanced ICT on the quality, reliability, and sustainability of smart city infrastructure? RQ6: What are the sustainability and policy-making implications for an evolutionary maturity model of smart city research? |
| Milchram et al. [41] | Explores the effect of moral values on the acceptance of smart grid technologies, and social and societal barriers for smart grid acceptance. | N/A |
| Noguera et al. [39] | Paper presents a novel mobile recommender system that brings together a hybrid recommendation engine and a mobile 3D GIS architecture. This system allows tourists to benefit from innovative features such as a 3D map-based interface and real-time location-sensitive recommendations. | RQ1: Are 3D maps a good way to provide location-aware recommendations on mobile devices? RQ2: Does location-awareness increase the quality and usefulness of the system? |
| Perego et al. [44] | Aim to classify research on information and communication technology (ICT) for logistics and freight transportation on the basis of the main themes and methods and proposes directions for future research. | N/A |
| Tomor et al. [23] | Study provides a mapping of expected influence of ICT on smart governance. The main objective of study is to generate a factual basis for debate by providing an overview of what is known about the context-dependent contribution of ICT enabled citizen-government collaboration to urban sustainability. | RQ1: What relationships exist between ICT-enabled citizen-government collaboration and sustainable urban development and how do contextual circumstances influence these? |
| Torres et al. [47] | The study investigates the state of e-governance in local governments across Europe, discussing the level of development of use of ICT in e-governance initiatives. | N/A |

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**Table 10** (*continued*)

| Reference | Objective | Research questions |
|---|---|---|
| Viale Pereira et al. [48] | Study addressing the concept of smart governance in a smart city context, analysing of how ICT can promote collaborative governance and increase the participation and engagement in government. | RQ1: How can ICT promote collaborative governance and increase participation and engagement in smart city initiatives? |
| Wang et al. [40] | This study aims at investigating tourists' preferences of smart tourism quantitatively in a tourist attraction context. | RQ1: What are the tourists' preferences of smart tourism quantitatively in a tourist attraction context? |
| Zander et al. [32] | The study addresses barriers to and facilitators for implementing welfare technology for older people and persons with disabilities, synthesizing evidence form reviewed literature. | N/A |
| Zhao et al. [21] | Aim of the review is to provide a comprehensive picture of the state-of-the-art of research in smart cities by addressing major issues and identifying gaps and areas for future research. | RQ1: What are the noticeable developments in smart city research? RQ2: What are the major focus areas of smart city research and what has been achieved in these areas? RQ3: What are the most important research areas that have been overlooked but need to be developed for future smart city research as well as for practitioners? |

**Table 11**
Technologies investigated in studies.

| Authors | Technologies investigated. |
|---|---|
| Abduljabbar et al. [29] | Big data, information technology, mobile computing, AI and data analytics, machine learning, sensoring technology. |
| Ahmadi-Assalemi et al. [24] | Cyber resilience and security in Industry 4.0, Cyber-physical production systems: IoT, big data. |
| Akhatova et al. [42] | Agent-based modelling. Urban district energy systems: group of buildings, heating and cooling infrastructure, distributed energy resources (PV, battery, solar thermal, heat pump, CHP), electricity distribution network. |
| Bacciu et al. [34] | Wireless sensor network (WSN) for AAL. Recurrent Neutral Networks (RNN) as a machine learning model for processing of the sensed data produced by the notes of the WSN, within a RC – an echo state network (ESN) paradigm. |
| Bonsón et al. [46] | ICT, web-based solutions (social media, Facebook) |
| Brohi et al. [22] | Mobile smart healthcare applications, smart urban planning using big data analytics, IoT with machine learning for detecting traffic and pollution. Big data for supporting low-carbon road transport policies. |
| Caputo et al. [31] | Digital ecosystems, ICT |
| Carolan [37] | Agro food-based technologies such as big data and precision farming. |
| Chung and Koo [38] | ICT, Web-based solutions/social media. |
| Dashkevych and Portnov [27] | ICT, sensors, infrastructure, new technology, open data, AI, IoT, machine learning, smart building, big data, road mapping, smartphone app. |
| Fahmideh and Zowghi [26] | IoT platforms. |
| Francini et al. [43] | IoT, mobile cloud computing, autonomous vehicles, blockchain, GPS, sensors, big data, machine learning, connectivity. |
| Green et al. [35] | Management support (sensors, AI, machine learning, robotics), connectivity in food systems (suppl. Chain management tech., DLT, expansion of ICT), novel foods (e.g., cellular agriculture), UAV, CEA, big data, precision agriculture. |
| Hasan et al. [45] | Autonomous vehicles, AI transportation systems. |
| Huang and Thomas [28] | Living labs: ICT, software applications, big data. |
| Huang-Lachmann [20] | Smart mobility and smart living applications in climate change adaption, and Smart technologies or approaches applied in climate adoption to increase competitiveness (smart economy) – ICT, GIS, data analytics, computational modelling. |
| Jin et al. [36] | IoT, sensors and AI. |
| Khosrojerdi et al. [25] | (AI-based) smart grids. |
| Latikka et al. [33] | Physical ICTs: robots, wearables, and smart homes (AAL) |
| Lee et al. [30] | Privacy-preserving smart home system with community hierarchy; ICT, IoT and data analytic solutions. |
| Lytras and Visvizi [2] | Smart city ICT services. |
| Milchram et al. [41] | Smart grid technology; ICT, big data, IoT and AI. |
| Noguera et al. [39] | Mobile computing, GPS, GIS, and 3D mobile technologies. |
| Perego et al. [44] | ICT systems, Group decision support systems, Real-time decision support systems, Wireless Field Force Automation applications, intelligent web-based systems. |
| Tomor et al. [23] | ICT in human-related interactions by connecting issues of government, technologies, collaboration, citizen participation, and sustainable development. |
| Torres et al. [47] | ICT, internet, web sites. |
| Viale Pereira et al. [48] | Smart governance ICT: data sharing, monitoring systems, integrator systems, geo-located based data, data-based decision-making processes, real-time data, big data analytics, data crossing, media/social media. |
| Wang et al. [40] | ICT-integrated tourism platform – cloud computing, IoT, AI and mobile communication. |
| Zander et al. [32] | Welfare technologies e.g., mHealth, smart home technology, sensors, robotics (bathtub, shower, telecare, SSH). |
| Zhao et al. [21] | Smart technologies, applications, big data, systems, architecture, infrastructure, and issues of technology diffusion. |

**Table 12**
Findings, authors conclusions, and knowledge gaps.

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| Abduljabbar et al. [29] | New technologies can simplify bike-sharing usage and enforcement of bicycle returns by using publicly available station level data. During 2019–2020, more focus was given to topics around "data", "social media", "parking", "agent-based modelling" and "dock less bike-sharing". The | Despite valuable research contributions that represent fundamental knowledge on this topic, today's body of research appears quite fragmented in relation to the role of micro-mobility as a transformative solution for meeting sustainability outcomes in urban environments. | Research that targets framework for rethinking urban mobility; research that aims to develop agile policies and regulations; research that prioritizes practical routes for informing urban mobility policies that consider both immediate and long-term impacts though field and modelling studies. Short |

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**Table 12** (*continued*)

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| | country analysis showed that the highest cited countries in micro-mobility research were the U.S. (2919 citations), followed by the U.K. (1474 citations), Australia (1291 citations), Netherlands (1291 citations) and Canada (620 citations. | | and long-term impacts of tech-enabled mobility solutions, evaluation of impacts frameworks that are rigorous and comprehensive, research innovations that integrate micro-mobility, active transport and public transport and governance frameworks that are outcome-focused to overcome barriers to urban innovations. |
| Ahmadi-Assalemi et al. [24] | Find that cyber–physical systems (CPSs) addressing cyber resilience and support for modern digital forensic incident response (DFIR) are a recent paradigm. | Smart sectors like smart healthcare and smart citizen were addressed only by a small number of studies, and it is critical that future research recognizes this limitation. Authors find that there is an increasing interest in theoretical research and empirical implementations of CPS cyber resilience and support for modern DFIR within smart cities. | Suggests that future research could focus on applying CTI to modelling attacks on entities' critical functions and underlying systems including its people, processes, and technologies. Authors further identified a lack of available current publicly accessible real CPS-generated datasets that limit the ability of comparative experiments e.g., to test and validate the accuracy of results robustly, and that future work could consider addressing this limitation to create a pool of scientific resources. |
| Akhatova et al. [42] | Authors point to great potential in Agent-based Modelling (ABMs) to help policymakers make better policy decisions, especially in the upcoming years of post-covid recovery. The analysis reveals that the most established agent-based models' focus on innovation diffusion (e.g., adoption of solar panels) and dissemination of energy-saving behaviour among a group of buildings in urban areas. Authors further points to a considerable gap in exploring the decisions and interactions of agents other than residential households, such as commercial and even industrial energy consumers (and prosumers). | Agent and model level parameter selection is often not given the due respect and attention it deserves. As the energy system complexity and, hence, the model complexity increase, careful parameterisation can significantly lower the computational cost. | The main challenge for future ABM applications in district energy systems is whether the ABM concepts can evolve and scale-up to represent the complexity of agents' decisions and interactions in a smart and decentralised energy system. (…) There are still many gaps and potentials in studying how to encourage the transition of consumers towards prosumers. (…) There is potential in exploring phenomena that involve multi-level decision-making and interactions of various stakeholders. |
| Bacciu et al. [34] | The experimental results point out that the proposed LI-ESN (leaky integrator, a variant of a standard echo state network (ESN) model) approach achieves very accurate predictions of the user spatial context without resorting to a large (over 100 units) reservoir, while showing robustness to variations to the monitored indoor ambient. | Overall, the results of the empirical analysis suggest that LI-ESN has an excellent trade-off between accuracy, generalization, and efficiency, when dealing with noisy time series data. As such, it can be considered a good candidate for the development of a distributed learning system for AAL applications that embeds the LI-ESN modules directly on the wireless sensor nodes. | Wireless Sensor Network (WSN) for AAL raised novel challenges related to the effectiveness and efficiency in treating sensed, temporal data. Prior studies had purposed experimental analyses with a limited scope and founded only on artificial data. |
| Bonsón et al. [46] | Social media are helping to empower citizens and expand democracy. Communicational differences across public administration styles exist. Different media and content types have a significant impact on citizens' engagement. | The results show that marketing related contents are preferred by local governments in Western Europe, while citizens prefer topics related to municipal management more closely related to their everyday lives. Results also show that engagement levels by citizens are higher in those local governments which allow wall posts by stakeholders. Further, engagement levels by citizens seem to be dependent upon the public administration style, confirming the importance of the institutional on e-participation and citizen engagement. Study also finds that citizens in those settings with historically scarce opportunities for citizen participation are now making greater use of the available technology to engage in discussions about local issues, which seems to confirm that SM are helping to empower citizens and expand democracy. | Local governments have started using Facebook as a communication and reporting channel, although clear evidence about its impact or whether it means any change on government-to-citizen (G2C) relationships is still missing. |
| Brohi et al. [22] | The IEEE Access journal and IEEE Smart Cities Conference are the leading sources of literature containing 10.34% and 13.88% of the publications, respectively. The current state of the research is semi-matured where research type of 46.15% of the publications is solution and experience, and contribution type of 60% of the publications is architecture, platform, and framework. Prescriptive is least whereas predictive is the most applied type of analytics in smart cities as it has been stated in 43.08% of the publications. | The authors identified that there is substantial big data research produced in the areas of smart transportation and smart environment. | A need for more research efforts in the areas of smart healthcare, smart governance, smart safety, smart education, and smart energy. Furthermore, the potential of prescriptive analytics in smart cities is also an area of research that needs to be explored. |
| Caputo et al. [31] | The main finding is the identification of possible advancements in the management of Digital Ecosystems using the evidence offered by the evolution of Smart Communities. Further, information and Communication Technologies cannot be considered only as an instrument to support the management and the functioning of Digital Ecosystems, but they can also create the better environment to support an autonomous | Paper helps develop a common interpretative scheme to better understand the logics and dimensions of the Ecosystem view. | A wider study on the interpretative schemes that influence dynamics of Digital Ecosystem should be developed in order to better understand opportunities and limits related to the 'coevolution' of digital and social dimensions. |

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**Table 12** (*continued*)

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| | interaction among different resources and actors able to define rules and principles of the emerging networked systems. | | |
| Carolan [37] | Interviewees discussed issues related to access, property, and sovereignty: i) justice, ii) ontology, and iii) claims making. Justice: rights-based (having the right to access) versus capacity-based (capacity for access or ownership "in ways that generate material wellbeing"). Ontology: Individualistic (e.g., seeing neighbours as competitors and typically leaning on rights (-based)) versus collectivistic (community perspective and typically leaning to a capacity (-based) approach. Claims making from centralized to diffused, or a hybrid position focusing on local community. | In conclusion, this analysis revisits the concept of access, and to a lesser extent property/ownership, through a critical social science lens. The above framework affords a conversation about sociotechnical assemblages in terms of what they do and the political ontologies they engender, recognizing, for instance, that while access can afford individuals and groups benefits it can also detract from an individual's and/or group's ability to flourish. Being able to identify those practices of agro-digital governance that afford sovereignty can inform policies and programs by nurturing an understanding about the worlds they may make possible. | N/A |
| Chung and Koo [38] | Findings revealed that the travellers' perception of the value of social media is a primary determinant of the traveller's social media usage. This study reveals that using benefit and sacrifice together can give a deeper understanding of an end-user usage and decision making. | The users of new social media, especially for travel information searches, are influenced by both benefits (information reliability, enjoyment) and sacrifices (complexity, perceived effort). However, only enjoyment makes an impact directly on social media usage. | Future studies may extend authors research model by including components of cognitive and affective factors to examine decision making for travel information searches. |
| Dashkevych and Portnov [27] | Identifies 48 smart city identification metrics across three categories: (1) smart digital technology, (2) living conditions, and (3) environmental (ecological) sustainability. Criteria or metrics sorting under the first category seems most popular, while criteria from category three is applied less often. Further, only half of the criteria's used relates to citizens' needs, while the rest being general technological measures. | This classification differs from traditional SC categorizations in which some categories contain more metrics than others and many metrics are general technological measures not directly related to human welfare. | (1) Ranking SC criteria according to their temporal attributes (i.e., short-term progress evaluation vs. strategic long-term impact assessment), and (2) ranking SC evaluation metrics according to their performance in assessing the extent of a city's "smartness". |
| Fahmideh and Zowghi [26] | One-size-fits-all assumption is not a practical choice: One cannot claim that one approach is superior to another. The selection of an IoT development approach depends on the requirements and context of the IoT project. Requirements analysis is missing: IoT development may face both technical and non-technical issues such as increasing number of stakeholders (as in a Smart City context) with diverse requirements, responsibility distribution, legal issues, commitment levels, etc. | IoT platforms are complex and multifaceted IT artefacts. Using systematic approaches are acclaimed to aid developers to manage the complexity of development and maintenance of IoT platforms in more cohesive and disciplined manner. An ad-hoc approach may result in poor and costly platform maintenance. | How to design situation-specific IoT-platform development approaches which can meet the requirements of a specific project. In addition, the current survey also calls for developing new IoT specific requirement engineering techniques that can address the complexity of large scale IoT architectures as early as possible in a platform development endeavour. Another identified area for more exploration is that the existing approaches suffer from defining a chain of model traceability and transformation. |
| Francini et al. [43] | Literature clustered into seven thematic areas based on analysis of keywords used in literature: (1) Computing for urban safety and efficiency, (2) Solutions for reducing energy consumption and pollution, (3) Sensors and advanced digital technologies to support mobility management, (4) Sharing to meet the demand of human mobility, (5) Sustainable planning for quality services, (6) Simulation and modelling to monitor mobility, (7) Accessibility and connectivity of transport networks. | The main elements that influence smart transition processes applied to mobility planning are technological innovation, environmental sustainability, and user satisfaction, in addition to the physical characteristics of the infrastructure system. Authors proposed definition of smart mobility: "the result of a planning process which makes use of technological supports in the simulation phases, use and monitoring of individual and shared transport systems to ensure safety standards, functionality and sustainability." | N/A |
| Green et al. [35] | Emergent coding revealed three clusters of digital agricultural technologies (DATs) that (1) make farm management more precise (e.g., sensors, AI, robotics), (2) increase connectivity in the food system (e.g., supply chain management technologies, blockchain, and expansion of ICT), and (3) create novel foods that replace current, resource-intensive agricultural practices (e.g., cellular agriculture). | While DATs hold promises to enhance ecosystem services (ES), technology on its own is insufficient to reduce the food system's environmental footprint. Hoped-for benefits remain largely hypothetical without sustained investment in technical training, policies to incentivise DATs adoption, and further research on the sectoral and regional use scenarios for DATs. | Need for better model agriculture systems and ecosystem services: Empirical research currently lacks the tools needed to measure and monitor multiple ecosystems across temporal and spatial scales and align ecosystems variables with decision-makers' management decisions. There is also a need for more efforts to contextually understand and describe changes that digitalisation produces on management decisions and consequences for agriculture–ecosystem interactions. |
| Hasan et al. [45] | Findings show that autonomous vehicles (AVs) can potentially reduce more than 80% of pollutant emissions per mile if powered by alternate energy resources (e.g., natural gas, biofuel, electricity, hydrogen cells, etc.). Findings revealed barriers such as technological uncertainties, lack of regulation, unawareness among stakeholders and privacy and security concerns, along with the fact that lack of simulation and empirical modelling data from pilot studies limit the application. AV–PT was also found to be the most sustainable | The research on private autonomous cars concluded with a positive outlook on the AV mobility if electric/hybrid electric autonomous cars were to be the driving force behind the system. | The review found that the majority of literature lacked in concise integration of stakeholder engagement, real-world traffic data, cost and emission models and detailed traffic simulation modelling for life-cycle implications of ITS and AV transport. |

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**Table 12** (*continued*)

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| | strategy in dense urban areas to shift the heavy trip load from private vehicles. | | |
| Huang and Thomas [28] | "Urban living labs" points out as an emerging sub-field within Living lab research. Identified eight thematic domains in terms of methods. Appendix 1 As for the tools used, these are in both digital and physical formatsAppendix A. The tools are often embedded in the methods used and should be examined along with the corresponding application method. | Authors draws a list of methods and tools used in living labs, contributing to sketching out current and common approaches in facilitating co-creation. | Small-scale contributions and weak interconnections imply that living lab research is not yet full-grown. Further, authors point to a lack of solid endorsement for theoretical foundations of living labs, posting a challenge to the integration into mainstream innovation literature. |
| Huang-Lachmann [20] | (1) Technology plays a key role in smart cities applications in climate change adaptation. Almost all definitions included the aspects of digital technologies and information communications technologies (ICT). (2) An environmental or sustainability concept is also often embedded in the smart cities definitions. (3) Smart people and smart governance are acting as the foundation together with smart environment dimension, (4) an integrated approach of combining climate adaptation and smart city is possible and beneficial. | "A smart city framework with six dimensions is a useful framework to make sure as many aspects are considered. The findings show that an integrated approach of combining climate adaptation and smart city is possible and beneficial. This could pave the way for future city policy implementation. The list of smart city applications in climate change adaptation aim to contribute to the exploration of developing indicators for smart city studies in climate change." | The understanding of the smart cities approach within the literature on climate change adaptation is a field worthy of increased attention and research. |
| Jin et al. [36] | "The proposed method can accurately predict changes in the next 24 h to meet the needs of precision agricultural production the next day. The development of the proposed method means that the temperature prediction accuracy is increased by about 1°, which is important for agricultural production". | "The proposed predictor has been used to predict temperature, wind speed, and humidity data in an agricultural IoT system. In practical applications, the proposed predictor can obtain accurate predictions for the following 24 h, providing sufficient climate information for precision production". | Need for more research on precise climate prediction in agricultural production. |
| Khosrojerdi et al. [25] | Use of intelligent systems falls into two main categories as follows: Focusing entirely on the technicality of the IT projects and highlighting impacts of implementing such projects on characteristics of the smart grid (Table 4 (smart grid improvements), 6 (business aspects) and 7 (infrastructure issues)). | So far, smart grids have been perceived as renewed and advanced power systems complying with new technologies involving ICT. However, the amount of data produced by new key players, including autonomous cars and smart cities, creates an environment that changes our perceptions of the smart grid. There is a need for identifying characteristics of this type of grid that represents a different identity. Technical features and definitions of this fast-approaching power grid need to be outlined in future works. Moving forward to a new generation of power systems, the forthcoming research can focus on defining the technical characteristics of the grid based on AIA innovations. | Moving forward to a new generation of power systems, the forthcoming research can focus on defining the technical characteristics of the grid based on AIA innovations. |
| Latikka et al. [33] | ICT solutions such as smart homes can help detect and predict loneliness and social isolation, and technologies such as robotic pets and some other social robots can help alleviate loneliness to some extent. | Technology can help assess older adults' loneliness and social isolation and alleviate loneliness without direct interaction with other people. The results are highly relevant in the COVID-19 era, where various social restrictions have been introduced all over the world, and the amount of research literature in this regard has increased recently. | The main open-ended challenges across studies relate to the need for more robust study samples and study designs. Further, the reviewed studies report technology- and topic-specific open-ended challenges. |
| Lee et al. [30], | The home controller performed data hiding and minimization by de-identifying source raw data and delivering them as aggregated data. Subsequently, the community broker achieved data aggregation and separation by further transferring the aggregated data after fusing the de-identified information with surrounding information. Finally, the cloud platform provided predefined public data for analyses, inquiries, and management while preserving privacy. | The platform enables controlling the privacy protection process and satisfies the requirements of advanced data analytics and applications. | More precise temporal division of public and private periods to enhance the flexibility of the settings. For personalized service, family member authorization should be expanded from households to individuals. |
| Lytras and Visvizi [2] | The main finding was that the following technologies are recognised as the critical components of smart city infrastructure: cheap broadband Internet (Wi-Fi), socially reliable networks, interoperable sensor networks, good electrical infrastructure, Internet of Things, and cutting-edge ICT (including business intelligence, Big Data, and analytics). | Building on the notion of end users' awareness of and ability to use applications and solutions considered "smart", authors argue that if smart cities research is to be sustainable, it also needs to be interdisciplinary. This, in turn, requires greater attention to be paid to conceptual precision, methodological meticulousness, and above all, metatheoretical awareness in smart cities research. | Paper suggests that more pragmatism needs to be included in smart city research if its findings are to remain useful and relevant for all stakeholders involved. Further, research originating in humanities and social sciences tends to reduce the centrality of ICT in smart cities research and, therefore, the depth and breadth of implications that emerge at the intersection of innate social problems and ICT in urban space remain underexplored. |
| Milchram et al. [41] | (1) Environmental sustainability and security of supply positively influence smart grid acceptance, (2) affordability, inclusiveness is driving factors for smart grid acceptance, while (3) concerns | Values are indeed discussed in the literature on smart grid acceptance and adoption. However, their relationship with acceptance is not always clear. Whereas certain values are always | The role of moral values as factors for smart grid acceptance in order to contribute to embedding values in smart grid design. Bridging literature from ethics of technology with technology acceptance. |

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**Table 12** (*continued*)

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| | about privacy, security, or health negatively impact their acceptance. | seen as either drivers or barriers, others could be seen as having an ambiguous effect on acceptance. | |
| Noguera et al. [39] | Testers have provided a very positive review of the application, pointing out the simplicity of its use and the usefulness of the real-time location-based recommendations. | The system fulfils the necessities required for on-the-move tourists: where I am, what interesting items can be found nearby, how far I am from them and how do I reach them. The details related to the design and implementation of a client–server application that implements these ideas were also provided. | Mobile devices present several usability limitations that should be considered in order to provide information in a direct and intuitive way. |
| Perego et al. [44] | In ICT adoption, many themes are under-represented in literature, such as the subject of integration among different application types, empirical research on ICT adoption and the role of technology providers in the adoption process. many of the papers examined are either conceptual papers or empirical studies (i.e., mostly based on surveys, or else on case studies or interviews), while simulation and modelling are rarely present. | While contributions from the "public" (i.e., institutional) perspective are generally older, papers focusing on the "private" (i.e., company) perspective are relatively more recent, and their number has progressively increased. Several important areas are under-represented. In general, what has emerged is the substantial lack of an up-to-date taxonomy that classifies the available ICT applications and functionalities for companies performing freight transportation activities. Moreover, the subject of integration among different application types is not adequately addressed. | (1) There is no up-to-date overarching taxonomy of available ICT applications for freight transportation companies. (2) Little attention has been paid so far to the integration among different application types. (3) Studies on the role of technology providers in the adoption of ICTs within logistics and transportation companies are rare. (4) There are very few applications of simulation and mathematical models to assess the impact of ICT adoption in logistics and transportation. (5) Little empirical investigation has been performed so far on some types of players in the logistics and freight transportation arena. |
| Tomor et al. [23] | (1) Smart governance, in the sense of ICT-enabled government-citizen collaboration to advance urban sustainability, is still rare. (2) The literature reveals the dominance of a one-way information supply in citizen–government interactions. | (1) ICT-enabled government-citizen collaboration to advance urban sustainability, and collectively shape public matters, is still rare. Old patterns, structures and routines still dominate. (2) The evidence that smart governance contributes to sustainability is sparce and mixed. Literature fails to elucidate whether smart governance activities lead to more liveable cities, i.e., cities with less social deprivation, more ecological diversity, and enhanced economic prosperity. (3) More evidence of the process effects of smart governance. "Citizen participation and learning can indeed be (achieved) goals as social aspects of sustainable development. However, many studies seem to treat ICT-facilitated citizen participation as a merit in itself—engagement for the sake of engagement without questioning its benefits for the society". (4) Contextual factors influence the role of governments and citizen as well as ICT use and define how local governments and citizen collaborate through electronic recourses. | The effects of smart governance on sustainable urban development have remained strongly understudied. There is a need for deeper understanding of the forces acting as a hindrance or encouraging local governments and citizens to engage in digitally supported collaboration in order to accelerate sustainability transition in cities. |
| Torres et al. [47] | All cities investigated are involved in e-government initiatives, albeit with different levels of development. Most common services offered are administrative procedures related to general, cultural, leisure, and sports services (e.g., municipal tax payment, booking of ports facility, public employments, and procurement, etc.) Local governments frequently use the Internet to offer information to citizens, but it is less common to use the Internet as a medium for two-way communication. "There are opportunities for (ICT) to enhance governance in local governments, but the focus of the ICT applications concentrates technologies on the management and delivery of services rather than on other areas." (p. 277) | Authors conclude that "technology is behaving as an enabler within pre-existing social and political structures". " e-government needs to be integrated into the broader public management reform framework. (…) ICTs have not had a dramatic impact on the practical reality of present politics (…) This perspective shows the difficulties of achieving radical change in public administration systems through technological mechanisms" (p. 300). | N/A |
| Viale Pereira et al. [48] | ICT has an important role in supporting information sharing and integration between government agencies and external stakeholders, including citizens, especially in developing countries. | (1) The study reveals data and information sharing as a key asset in municipal operations centre initiatives. (2) Study contributes to the literature gap "in which the role of ICT in increasing the engagement and collaboration of people in public debate was not fully achieved". "Data-based decision-making is one of the main results of the analysed initiatives for increasing the quality of public decisions." Following a definition of governance as a multi-stakeholder influencing decision-making process through increased interaction and collaboration , the study "affirm that ICT has been playing a role in initiatives supporting smart governance". | Authors note that the digital divide was noted as a concern when implementing smart city initiatives, thus, future research should explore the unintended consequences of smart city initiatives. |
| Wang et al. [40] | The research identified 28 key evaluation items of smart tourist attractions (STA) and grouped them into eight categories: "smart information system", "intelligent tourism management", "smart | Thus, tourist attractions should make an optimal use of smart tourism facilities by offering the right smart tourism devices and services that suit tourist preference at the right time. The ten most | Considering the central role tourist attractions play in the tourism system, the authors believe STA represents a fertile ground for future research, which |

(*continued on next page*)

**Table 12** (*continued*)

| Authors | Findings | Authors conclusion | Knowledge gaps |
|---|---|---|---|
| | sightseeing", "e-commerce system", "smart safety", "intelligent traffic", "smart forecast" and "virtual tourist attraction". The findings indicate that tourist preferences of STA are multifaceted, which include not only real-time information access, online booking and tourist-flow forecast before trip, but also effective tourist attraction management, personalized itinerary design, efficient transport, and smart safety during trip. In addition, sharing tourism experiences in virtual tourist attraction after trip is also essential for tourists. | important items preferred by tourists are tourist attraction homepage, smart vehicle-scheduling, personal-itinerary design, free WIFI, smart cards (bands), intelligent-guide system, crowd handling, mobile payment, tourist-flow monitoring, and online-information access. Those items should be given priority when building an effective STA. | deserves more scholarly attention. Lack of research on the investigation of smart tourism assessment. |
| Zander et al. [32] | The study finds that it is important to consider facilitating and hindering factors that influence implementation of welfare technologies. Six themes of facilitators and barriers that influence the implementation of welfare technology emerged: capacity, attitudes and values, health, expectations, participation and identity and lifestyle. These were presented from five perspectives: older persons and persons with disabilities, informal caregivers, health and care personnel, organisation and infrastructure and technology. | The study generates deepened insights and structures to guide and evaluate the implementation processes of welfare technologies and engenders an understanding of the complexities of implementation. | Need for longitudinal studies with quantitative and mixed-methods design exploring implementations of welfare technology from a user and organisational perspective. Further, need to extend or develop approaches for requirement analysis techniques that includes stakeholder identification and engagement. Need for more research on the identification of roles that are specific to IoT context. |
| Zhao et al. [21] | (1) Technology integration in smart cities needs to incorporate social integration, viewing smart cities as a whole and addressing the challenges of smart technologies in a holistic and integrative way. (2) Very few studies discuss in detail the downsides of technology and the failure of smart city projects. | Challenges in SC-research; (1) smart city research is often fragmented and technology-driven; (2) many studies are on the perceived benefits of smart cities and fewer on the downsides of technologies and failed projects; (3) there is a need to build new theories for smart city research; and (4) there is a lack of empirical testing of the conceptual frameworks developed in smart city research. See Table 2 for proposed key questions for future research. | Smart city research is fragmented, divergent and takes on many perspectives. There is a clear need for more holistic literature reviews to capture the overall picture and the essence of smart city research. Few have been able to capture both the scope and the depth of the prominent areas of smart city research. Research on equality, accessibility, and inclusiveness of new technologies in smart cities warrants more attention in smart city literature. |

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