Sustainability's Coming Home:
Preliminary Design Principles for the Sustainable Smart District

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Abstract. Consumer trends like local consumption, sharing of property, and environmental awareness change our habits and thereby our surroundings. These trends have their origin in our direct environment, in the districts of our city or community, where we live and socialize. Cities and districts are changing to "smart cities" and "smart districts" as a part of the ongoing digitalization. These changes offer the possibility to entrench the idea of sustainability and build a platform-based ecosystem for a sustainable smart district. This research aims to identify guidelines in form of preliminary design principles for sustainable smart districts. To achieve this, we conduct a structured literature review. On this basis, we derive and develop preliminary design principles with the help of semi-structured interviews and a non-representative sample of the German population. The resulting nine preliminary design principles describe a first insight into the design of sustainable smart districts.

Keywords: Sustainability, Smart District, Platform-based Ecosystem, Smart City, Design Principles

1 Introduction

Sustainability is a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. The goal of a sustainable development unites the world population more than any other goal in the past [2]. One concept to face sustainability in the area of living are smart cities. These smart city concepts foster sustainable development and face current challenges of our society like immigration, demographic change, and environmental pollution by the means of technology [3–5]. This is one of many reasons why the term "smart city" gained much relevance in the last years [6, 7]. A smart city is able to provide a connected and sophisticated infrastructure to foster economic, ecologic, social, and cultural matters [6] as well as a social-technical view [4]. Current consumer trends with focus on local markets, sharing, mobility, living, and environmental awareness

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influence the design of the smart cities and its contribution to sustainability [8–11]. Many companies like Uber or nextdoor already recognized the possibilities digital platforms offer in this context.

Since smart cities are very complex systems, it is much easier to plan them with a greenfield approach than on existing cities. To solve this problem, we reduce the complexity to a district perspective by focusing on smaller parts of existing cities. It is also possible to use this district idea for smaller municipalities like small towns, villages, or rural areas in general [12]. Furthermore, consumer trends often take place on a district level and contribute to the ecological, social, and economic development of the district. The implementation of sustainability in districts due to new mobility concepts, sharing concepts, and platform-based collaboration is already happening in many districts [9, 10]. Another example is the use of renewable energy sources for the electricity and heating demand of the district [13, 14]. However, to reach these benefits, there is a need for an adequate information and communications technology (ICT) infrastructure. This technological basis and the connection of all stakeholders lead to smart districts. There is no definition of smart districts in current research. Thus, we define a smart district, based on several smart city definitions and a statement on smart districts by the Smart Cities Information System (SCIS) initiative [7, 15, 16] as follows:

A smart district is a district performing in a forward-looking way in economy, people, governance, mobility, environment, energy, and living, built on a sophisticated, smart ICT infrastructure that ensures benefits for every stakeholder, in particular a high quality of life for every citizen.

The implementation of digital technologies in districts as well as a sustainable mindset, may lead to an ecosystem of a *sustainable* smart district (SSD). Since the term "ecosystem" has become pervasive over the past 20 years, it must be clearly characterized and classified for every research project [17]. For this, we see the SSD as an "ecosystem-as-affiliation" [17]. We consider a platform as the core, the SSD is affiliated with [18, 19]. Due to the central role of the platform, the wording "platform-based ecosystem" (PBE) gains relevance [18].

There are different kinds of platforms [20], which can be the core of a PBE. We see the platform in the SSD context as a digital platform from a sociotechnical point of view [20]. The definition contains not just soft- and hardware, but also organizational processes and standards [21]. Digital platforms stress the idea of modularity [22–24] especially regarding the peripheral components [25]. As Helfat and Raubitschek [18] state, digital platforms are often multi-sided platforms. Multi-sided platforms can be seen as markets that enable direct transactions among several customer groups, with strong network effects between these groups [26, 27]. Multi-sided platforms are of particular interest for us, since in the SSDs PBE many customer groups interact with each other and the value to one party depends on the number and quality of parties on the other sides of the multi-sided platforms [18].

PBEs are an emerging topic that demands extensive research. De Reuver et al. [20] set a research agenda for digital platforms and their surrounding ecosystems. Especially the question on '*how digital platform providers jointly shape platforms with other* *stakeholders*' is of particular interest for the present paper. However, there can be multiple stakeholders trying to influence the design of the PBE, and thus, the digital platform of the SSD and not necessarily one single platform provider. Therefore, we contribute to this scientific discourse by exemplarily analyzing one application: the PBE of the SSD.

Current literature is mostly dealing with sustainable smart city concepts [28–30]. This research often lacks a fine-grained district perspective. Since existing cities are very complex systems it could help transforming them piece by piece, using a district perspective. We identified various projects concerning smart districts like the district project "Smart District Gnigl" as part of the "Smart City Salzburg". The district project focuses on network and platform effects for local heating, mobility, and education within the district. Furthermore, we also consider smart districts in towns, rural areas, or as new village [12]. Examples for this are the "Smart District Mödlingen" or the "Steimker Gärten". However, there is little research tackling the adequate implementation and the theoretical background of the SSD. In times of global warming and social alienation, the guidance to a sustainable design is essential for the future smart district. Appropriate guidelines are necessary for understanding how smart districts become SSDs. In this paper we present a first step in this direction and build a theoretical foundation for the implementation of SSDs. We answer the following research question to identify preliminary guidelines for the SSDs PBE.

What are preliminary design principles for a platform-based ecosystem of a sustainable smart district?

2 Methodical Approach

Design Principles (DPs) are guidelines for building design artifacts within design science research [31]. The objectives of such design artifacts are to solve current problems [31] and provide an adequate level of novelty and utility [32]. Generalized prescriptions in the form of DPs aim at extending current design knowledge within this research domain [32]. Thus, DPs are recipes and guidelines for building or describing a specific artifact [33, 34], giving guidance on how to generate a new instance of a class of artifacts [35]. The DPs are usually derived from evaluating actual instances or more abstract conceptualizations [33, 34].

According to Hevner et al. [31], there are four possibilities for building artifacts: constructs, models, methods, and instantiations. For the PBE of the SSD the real-world instantiation is the most reasonable, because instantiations help researchers best to learn about the performance of the particular artifact in the real world [31].

Since there are not many realized smart districts and no SSDs, it is not possible to analyze an existing SSD PBE in detail. Before building an SSD PBE on our own, it is reasonable to first derive preliminary DPs (PDPs). Since there is not much research to SSDs yet, we created a first draft of these PDPs by deducing relevant content from related fields like smart cities with a structured literature review based on Webster and Watson [36] and Fettke [37]. Then, we further developed these PDPs in an iterative process with semi-structured expert interviews based on Myers and Newman [38] and Schultze and Avital [39]. Subsequently, we interviewed possible future inhabitants to gain insights from an additional perspective.

Our research is inspired by the design science cycles of Hevner [40]. In this paper, we were guided by the first rigor cycle by first conducting the structured literature review and then performing semi-structured interviews. The development of the PDPs is a deductive and conceptual process. On the one hand, our PDPs should incorporate already existing knowledge regarding SSDs [31]. Since there is not much research specifically to SSDs, our focus during the structured literature is deriving basic guidelines from related areas like smart city research. On the other hand, we follow a conceptual approach when grouping, formulating and narrowing down the first draft of principles. The interviews also helped us understanding requirements for the SSD, in terms of the relevance cycle. By focusing on the build cycle and deriving PDPs through a iterative process [32, 40], we contribute to the knowledge base on smart districts and form the basis for further operationalization of SSDs [34].

The evaluation framework by Sonnenberg and vom Brocke [41], consisting of four evaluation steps, inspired our research. During this process, we focused on their second step, to iteratively validate and justify our PDPs. Because this step should also encompass the stakeholders of the design artifact we have chosen expert interviews. In each of these interviews we received feedback regarding "ease of use", "efficiency", "generality", "operationality", "completeness", "elegance", meaning the language and structure of the formulations, "simplicity", and "understandability" [31, 32, 35, 41].

In order to contribute to design knowledge, we should ensure an appropriate level of applicability [31]. Therefore, we formulate our nine PDPs in a specific way, as described by March and Smith [32]. To guarantee a high degree of utility and efficiency, we follow the recommendations for precise formulations by Chandra et al. [33]. To consider these recommendations, we formulate our PDPs following the subsequent structure: "Provide the system with [material property – in terms of form and function] to [activity of user / group of users – in terms of action] […]." [33]. Therefore, our PDPs respond to efficiency requirements and maintain a consistent formulation [32].

3 Implementation of our Methodical Approach

To derive our PDPs for an SSD from current literature we conducted a structured literature review based on Webster and Watson [36] and Fettke [37]. We focus on inferring additional knowledge by the means of logical-deductive argumentation. For approaching the literature search in a systematic manner, we codified three search strings for three different research directions (Table 1). Then we evaluated the literature we found. Due to our focus on sustainability, we added this key word to every search string. The same applies to "ecosystem" and synonyms of "district". "smart" is the main prefix describing new digital concepts, no matter whether you look at "smart city", "smart home" or "smart living".

Table 1: Search Strings

Field	*Search string*
Energy and mobility	smart AND (sustainab* OR ecosystem) AND (city OR district OR town OR residential) AND energy AND (mobil* OR flexib* OR local)
Consumer trends	smart AND (sustainab* OR ecosystem) AND (city OR district OR town) AND (consum* OR local OR "sharing economy" OR governance OR residential)
Multi-sided platform	smart AND (sustainab* OR ecosystem) AND (city OR district OR town OR residential) AND ("multi-sided" OR platform)

We thoroughly selected the source material for the literature research. Webster and Watson [36] suggest starting the search within leading journals of the research field. "Sustainable Cities and Society", "Cities" or the journals included in "Senior Scholars' Basket of Journals" could represent important journals for our studies. Since the databases of the main academic publishing houses like SpringerLink or Elsevier contain each of these selected journals, we used these databases in combination with few others to also consider literature from other disciplines [36].

Our search-strings lead us to 4.076 papers, which we evaluated. After screening the titles, 265 publications were left and after reading the abstracts, 95 publications remained. Using those papers, we performed a backward and forward research.

To enhance our first draft of PDPs, which was solely based on the literature we found, we conducted eight expert interviews. We once interviewed three experts at the same time (E4, E5, and E6), and the remaining experts separately (Table 2). We recorded all interviews, which lasted approximately 60 to 90 minutes.

Table 2. Interviewees: Experts

	Business Domain	*Interviewee*	*Employees*
E1	Research Institute	Research Assistant	> 100
E2	Research Institute	Research Assistant	> 100
E3	Real Estate Management	Head of Fund Management	> 500
E4	Engineering Office	Managing Director	> 250
E5	Engineering Office	Consulting Engineer	> 250
E6	Engineering Office	Consulting Engineer	> 250
E7	Research Institute	Research Assistant	> 100
E8	Sustainable City Development	City Planer	> 50
E9	Research Institute	Business Development Manager	> 25.000
E10	Research Institute	Research Assistant	> 100

Inspired by the *design as a search process* of Hevner et al. [31], in the following paragraph, we first illustrate how we developed the PDPs. Subsequently, we present our resulting PDPs in Section 4.

We received relevant feedback in form of practical insights and improvements for the PDPs from the interviews. The feedback is the basis for changes of the PDPs, regarding the selected criteria "ease of use", "efficiency", "generality", "operationality", "completeness", "elegance", "simplicity", and "understandability" [31, 32, 35, 41]. Due to these we adjusted our first draft of PDPs and emphasize important aspects of the SSD. For instance, PDP7 was no part of our first draft. In this case, we got advice from research experts that visionary objectives and goals are crucial for the SSD. Following, the criteria of completeness was not fulfilled. Therefore, we revised relevant literature and formulated a corresponding PDP. One further adjustment was the division of a general IT PDP to PDP3 and PDP5 to reach the criteria “generality”. However, some of the comments were contrary to literature or other experts. For example, E7 recommended the exclusionary use of the term “stakeholders” in all PDPs. We followed this recommendation except for PDP5, where we kept the term “user” instead of “stakeholder” in favor of the criteria “understandability”. Most feedback faced the criteria “understandability” and “elegance”. For example, we reformulated PDP2 after feedback from E4, E5, and E6, to make clear, that stakeholders can be physically outside of the district. With respect to ”ease of use” and “operationality”, our interview partners gave us valuable recommendations with respect to the implementation in practice. We mitigate PDP9 because E4 noted that complete legal certainty is not reachable in the scope of current legal processes. The demand for changes by the experts shrank from interview to interview. We conducted the major structural and content related changes during the first four interviews. In the last three interviews we did not conduct major changes in the PDPs. In these interviews the experts mainly confirmed the PDPs, sometimes with notes regarding “elegance” and “understandability”. Due to their confirmation, we think that our PDPs reached a solid status [42].

We also started with an ex-post validation. Therefore, we conducted interviews with possible future inhabitants. Hence, an appropriate sample should include different groups of society to avoid a possible elite bias [43]. Patton [44] states that under the conditions of academic work such an evaluation is nearly impossible to reach. Therefore, each research should determine a minimum sample size [44]. We talked to 17 potential residents with diverse characteristics (Table 3).

Table 3. Interviewees: Sample of German population

Sex		*Age*		*Education*		*Gross Income*		*Household Size*	
female	8	18-29	6	academic	7	< 15.000 €	7	1 person	6
male	9	30-60	6	non-academic	10	15.000-60.000 €	5	2 persons	6
		> 60	5			> 60.000 €	5	>2 persons	5

4 Results: Preliminary Design Principles for the SSD

In this section we give an overview of our nine PDPs for the PBE of the SSD, which we derived through an iterative process [31, 40] based on a structured literature [36, 37] review and several semi-structured interviews [38, 39].

PDP1: Define adaptable spatial boundaries of the SSD to be able to identify the given characteristics and properties of the SSD.

“Spatial boundaries” stand for a physical connected area of an SSD. The spatial delineation impacts the quality of the SSD out of an environmental, social, and economic perspective [45]. A suitable layout of the SSD fosters sustainable projects and increases the quality of life within it [45]. “Characteristics” describe the geographical location as well as price levels and other intangible attributes. One of the most important distinctions for each SSD project is the difference between districts in cities and districts in rather rural areas. “Properties” stand for different kinds of buildings or public places in the SSD. The SSD should be mixed in its types of buildings, inhabitants, and institutions [45]. This also extends to the importance of mixing social classes and people with different backgrounds. This contributes to sustainability mostly in strengthening the social structures between the inhabitants. Mixing also leads to local labor and consumption within the SSD, which concludes in less transport efforts and more social cohesion. Many experts also emphasized, that these boundaries must be adaptable in case of a changing environment. Especially E9 and E10 stated that there are many different characteristics which can define the boundaries, like buildings or the electric grid.

PDP2: Identify stakeholders taking part in the PBE of the SSD to assign roles.

Hollands [6] concludes, that smart cities start from the human side. In the same way it holds for SSDs. Because of this, every SSD needs to aim for increasing the quality of life of their citizens [46]. For this Cacho et al. [46] suggest the identification of the different stakeholders as one of the first compulsory steps. According to Kennon et al. [47] and E10, the classification is important for designing the digital infrastructure in a suitable way. The identification of all relevant stakeholders is the foundation for cooperation and coordination of investments [48]. Since we focus on the PBE of SSDs, the producers, consumers, providers, and the owner are the basis, which should exist in every SSD [19]. Nevertheless, there are many more different roles in the SSD context [46, 48, 49]. One crucial role is the leader role [18, 50, 51]. This PDP contributes to sustainability by forming the foundation for a social sustainable togetherness. On the other side it also supports economical sustainability by helping to understand the needs of specific stakeholders.

PDP3: Provide the SSD with an adaptable and scalable digital infrastructure to integrate heterogeneous, connected IT systems and features, to facilitate the PBE.

Like smart cities, SSDs depend on the correct and meaningful applications of digital technologies like open data [52], large-scale distributed systems [53], internet of things (IoT) [54], cloud, and fog computing [55] to everyday life [4]. Since everybody in the SSD context should be able to easily design, develop, execute, and share content [49, 56], we consider a central digital platform as core of the whole ecosystem. Hence, we use the term PBE in this context [18]. One possible application of this platform is the field of energy. It can interconnect several energy and legacy providers, virtual power plants, and households [57]. The digital platform can automate network management, enable peer-to-peer energy sharing, minimize operating costs, lower the emission of greenhouse gases, control the electrical energy production as well as the electric vehicles charge/ discharge, and implement demand side integration [13, 58].

Due to the penetration of digital services through all areas of life, the SSD generates a vast amount of data [59]. Big data analysis can improve the performance of SSDs in many areas like energy or mobility, by accomplishing trend analyzes, forecasts or demand planning [59]. According to Cacho et al. [46], it is also possible to generate data from citizens by using social media. As Cacho et al. [46] and E10 stated, the SSD should use the ICT infrastructure and the platform primary as enabler to improve the life of citizens. This can be a chance, especially for SSDs in rural areas, to distinguish themselves from other municipalities, which often do not have the digital infrastructure to attract many people. Furthermore, the SSD should enable the development of innovative green solutions and services, to facilitate a more sustainable smart district.

PDP4: Establish a transparent, cooperative and participatory structure to enable collaboration and competition between stakeholders.

Darking et al. [60] as well as Helfat and Raubitschek [18] emphasize designing governance as a crucial issue. The structure of the SSDs PBE should be transparent and open for all stakeholders to foster cooperation and participation [61]. The claim for transparency comprises the political system, processes, services, market conditions, and the digital platform itself [62]. "Cooperative" means that stakeholders should form partnerships among each other and with actors from outside. Public participation in the form of collaborative decision-making empowers inhabitants of the SSD to express their needs [49, 56, 61]. This implicates market competition and collaboration regarding the distribution and control of resources and power within the SSD [62]. Such cooperative partnerships can lead to desirable synergy effects resulting in benefits for all stakeholders [63]. We do not see competition and collaboration as contrary extremes, but as driving forces for value creation within the SSD [64]. A transparent, cooperative, and participatory structure enables sustainable economic growth and fosters social cohesion. This follows from the involvement of people in the SSD processes and the open and integrating structure [50].

PDP5: Design the services of the SSD in a simple and accessible way to integrate all users.

This PDP prescribes that the services in the SSD have to be user-friendly and people-centric to integrate participants of all age and with every level of education [65]. Designing services in a simple way aims at the usability of these services. Hence, participants will use newly developed services within the SSD more frequently, if the offered solution is intuitive [66]. Including the stakeholders of the SSD in the service creation process strengthens the market competition. Hence, it improves the overall quality and price of the offered services [50].

PDP6: Determine tangible and intangible values to derive an incentive-structure and enable the development of value-adding services, to satisfy the stakeholders' needs.

Tangible values like financial gains are measurable, whereas intangible values are difficult to measure directly. An example for an intangible value is the provision of clean air. The values of the SSD lead to an incentive structure for the stakeholders to encourage their participation and value creation in the SSD [51, 67]. This means, the incentive-structure must be that attractive, that people want to collaborate, for example in either offering services for the SSD, or in using them. There is a strong connection between the services and the incentive-structure, because everybody offering a service wants to benefit. An appropriate incentive structure and value-adding services foster sustainability in various ways. For instance, the waste of food can be reduced by different kinds of food sharing concepts, implemented in the SSD. Additionally, there is potential value for local vendors, due to price reductions for surplus stocks or perishable goods. For the consumer it satisfies needs, by being economically beneficial, because he can purchase the food cheaper than in other circumstances.

PDP7: Continuously monitor the SSD and evaluate feedback to achieve or iteratively adapt visionary objectives and goals.

Literature and experts confirmed, that goals are necessary for the SSD, hence, they are a critical element of the PBE [68]. To ensure that all stakeholders work together, the planner should involve all relevant stakeholders in the finding process [69]. According to Slocombe [69], you should place additional visionary objectives on top of the goals, giving the stakeholders an overall vision for the future development of the SSD. These goals and visionary objectives should also target the implementation of sustainability actions in the SSD [28]. The responsible stakeholder groups should also accompany and reflect the process towards the optimal state [69]. We divide this control mechanism into two different elements. The first is rather quantitative monitoring, the second qualitative feedback. With the help of smart meters and similar devices authorities can automatically check goals. Resulting data sets give indications for future improvements [70]. The other approach of getting feedback from stakeholders of the SSD is more qualitative. This leads to better included stakeholders [56]. After monitoring and considering the feedback, it can make sense to adjust the objectives and goals. For this it is necessary to iteratively adapt these (E10).

PDP8: Integrate public and IT security concepts to provide safety for people, public, and private property.

We will reach sustainable development, if every stakeholder feels safe and protected within the SSD. According to Chifor et al. [71], applications or smart objects, which enable a new way of interaction between humans and their environment, have to consider security aspects. Furthermore, the huge amount of data gathered from different application and services is an issue [70]. It is necessary to ensure that the data is provided for the systems when it is needed. But at the same time, the SSD has to consider the privacy concerns of the people [70]. Furthermore, it is important to still be aware of the “traditional” security aspect for private and public property. For instance, countermeasures must be prepared if the energy supply breaks down.

PDP9: Comply with current law and regulations to aim for legal certainty.

The PBE of the SSD offers lots of chances but its value depends to the regulatory environment [58]. One exemplary regulatory aspect within the SSD is the energy market design. There are several laws that determine which designs are allowed and how taxes and fees are distributed [13]. Today, the regulation in most countries does not allow local peer-to-peer energy sharing [13]. If it were allowed, it would be a viable approach to integrate renewable energy sources in an economical way [13]. However, it is crucial for the SSD to meet current regulatory requirements [13] to target legal certainty. According to E4, it is not possible to achieve full legal certainty because the legal texts leave gaps whose interpretation depends on the opinion of a judge.

5 Discussion

We conducted interviews with ten experts from research, business, and the public sector. All our interviewees are originally from Germany. This represents a limitation of the paper. Experts with other cultural backgrounds could gain alternative insights and improve the PDPs. Furthermore, we conducted interviews, just with a small sample of the German population. The input of 17 people is a brief insight and should be pursued with a bigger number of participants to get representative results. With representative results the planning authorities can ensure that research and real-world projects fulfill the needs of potential inhabitants. Further, we did not conduct an empirical survey on the acceptance of the PDPs in the population.

These limitations in combination with statements of experts as well as parts of the German population point out the critical aspects of this research. Some experts emphasized certain arguments as very important for a successful SSD. According to E9, the trade-off between complexity and economic value is one of the most important aspects of the PBE of an SSD. The SSD must be financially viable and attractive for different stakeholders to successfully implement it in real life. Furthermore, E1, E8, E9, and E10 highlighted the importance of the human and their needs as center of attention within the PBE.

The interviews with a sample of the German population generated insights in the perspective of possible inhabitants. Almost all these interviewees stated that they can envision to live in an SSD. The main incentives they see are a more convenient and sustainable living. Especially the sample of the people above the age of 60 also stressed, that an SSD offers possibilities for people that need help in their everyday life. However, this part of the population was most concerned about losing control and responsibility for their lives. A part of the interviewees in the age between 18 and 60 raised questions about the financing of the SSD. The question who pays for the infrastructure is a relevant decision criterion to them. The question about the financing leads us to an even more relevant question: Who is in charge of the SSD. In the smart city context, current research discusses about private as well as public responsibility [63]. The success of the SSD depends significantly on the stakeholder of the district. Are there sufficient incentives for big and small stakeholders to participate? Which and how much stakeholder must be part of the district?

Some opinions about the concept of the SSD are very similar over the whole group of interviewees. For example, the demand for transparency of the PBE and to the same time the fear of data abuse. However, we found conversely opinions regarding the provided services and priorities of the SSD. Because of the different needs of the groups, there could be an increased risk of pooling inhabitants with similar backgrounds. The responsible authorities should counteract this development in an early stage by balancing the incentive structure and the price level of the SSD. Furthermore, it is questionable which influences multi-sided platforms have on the quality of the provided services. Cennamo et al. [72] illustrate that combining services on platforms can have significant influence on performance within the platform. In general, the SSD still contains open questions and potential undetected risks.

For regular cities, towns and rural areas the emergence of SSDs is a big opportunity. District projects like "Smart District Gnigl" from Salzburg or the German "Open District Hub" project promise to gain important insights in practical benefits of SSD projects. Especially the implications on remaining cities are very important for future district projects. It will help to evaluate a piece by piece approach for transforming cities with the help of SSD concepts.

6 Conclusion, Implication, and Further Research

The idea of a sustainable smart district as a platform-based ecosystem is very complex due to its variety of parties and implications. For this young field of research with rare practical applications, we enforce the awareness of sustainability within the concept. Due to that, the sustainable smart district has a need for preliminary design principles as a way of guidance. With these preliminary design principles, we ensure the consideration of ecologic, economic, and social factors in the district. In this paper we derive nine preliminary design principles from literature as a foundation for the design of the platform-based ecosystem of the sustainable smart district. We developed these principles in an iterative approach based on expert interviews. Furthermore, we interviewed a sample of the German population to ensure their acceptance.

There are many potential topics for further research in the sustainable smart district. First, a real-world instantiation enables the real-world evaluation of the preliminary design principles and carries on the research about sustainable smart districts. After carefully analyzing the results of this instantiation, we could finally evolve the preliminary design principles to design principles in the sense of design science research. Subsequently, we are able to evaluate these design principles according to Sonnenberg and vom Brocke [41], through an extension of the interviews on a complete average of the population. Third, experts from other disciplines and countries would gain further relevant insights to the topic. Fourth, a maturity model for the sustainable smart district would help to understand and classify potential districts. This is especially helpful to capture the current level of sustainability or digitalization within the sustainable smart district. We can also think of evaluating specific technologies or trends in the district context. For instance, future research could find out in which way sustainable smart districts could enable energy sharing within one, but also among several district and thus lead to ecological sustainability. To fully unpack the potential of SSDs, one must also investigate its links to emerging technologies such as electro mobility, smart traffic systems, big data analyses, and much more from a district point of view. Additionally, the three components of sustainability (social, environmental, economic) could be examined in detail, to derive specific recommendations to reach sustainability in the smart district. Furthermore, we raised some open questions in the discussion section, which serve as foundation for further research.

Our results represent a necessary foundation for the following applications in real-world and in science. For the realization of sustainable smart districts our guidelines can help to ensure a sustainable and feasible approach. New research projects can push the idea of the sustainable smart district to concrete concepts and prototypes. In this development a strong cooperation between research and practical application ensures a successful implementation. We believe that this paper contains applicable research, which guides real world projects in creating sustainable smart districts and develop districts, rural areas, and cities towards sustainable future living.

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