Journal of Ubiquitous Systems & Pervasive Networks
Volume 19, No. 1 (2023) pp. 39-46

Sharing Digital Solutions with the Public for a Climate-Friendly Smart City District via an Ecosystem Map: Concepts and Solutions

Frank Elberzhager, Anna Schmitt, Sven Storck, Stefan Schweitzer

Fraunhofer IESE, Germany, Fraunhofer-Platz 1, 67663 Kaiserslautern

Abstract

Climate change and its consequences are currently a very pressing topic. This is also true for cities. Digital solutions can be helpful in this regard. They can be used, for example, to inform citizens and provide digital services aimed at fostering climate-friendly behavior. In the EnStadt:Pfaff research project, we are developing a climate-friendly smart city district. Our focus in the project is on digitalization, with the main goal being the implementation of a digital ecosystem providing apps to the people of the district, which is currently under construction. To date, we have developed several digital solutions with different technology readiness levels. One major issue we have faced, however, has been how to inform the public about these solutions and share our ideas with them. We decided to do this in various ways, e.g., via a classical project webpage, events, and videos. In order to have one main entry point for the public to explore our solutions, we have developed a so-called ecosystem map. Four digital solutions are presented in this map to show what kind of digital solutions might be part of the future digital ecosystem in the smart city district. In this paper, we report on how we created the digital map, provide the four digital solution examples shown on the map, and present feedback we received regarding our solutions. This has also led to ideas for the future development of the map. We share three basic ones in this paper.

Keywords: *Smart City; Sustainability; Digitalization; Information Sharing; Digital Ecosystem Map*

1. Introduction

The digital transformation surrounds us everywhere [1]. It influences companies, municipalities, and our everyday life and leads to the emergence of new business models and services. Cities have not been exempt from this development in recent years and increasingly offer digital services [2][3]. Besides the digital transformation, topics such as sustainability and climate change are also of high relevance for cities. Specifically, cities have to deal with aspects such as mobility, energy, building, or heat, and develop new solutions [4][5]. The digital transformation can provide support in these endeavors (e.g., [6][7]). The climate change topic is omnipresent today, and every day, a multitude of articles appear, e.g., in journals, blogs, or newspapers, that address this topic from a social, political, technical, or other perspective. However, while there is general agreement on the need to become more climate-friendly, there are strong discussions about how to achieve this.

In 2017, the EnStadt:Pfaff research project started with the main goal of developing a climate-neutral smart city district. This district is being built on a former industrial site of a well-known sewing machine manufacturer, which covers an area of approx. 18 hectares and is being redeveloped as a living and working environment for citizens. Topics such as energy, mobility, community, digitalization, and smart home are the project's focal areas. A long-term goal in the realization of the district is the development of a digital ecosystem composed mainly of a platform and digital services to help citizens act in a climate-friendly way. As one of the partners in the research project, we are responsible for such a digital ecosystem and are developing various digital solutions and prototypes to support future citizens of the district in engaging in climate-friendly behavior.

One of our guiding principles is to involve as many people as possible. In the past, many people in our city had some connection to the former company in the district, so they are interested in what happens to the district. This helps us to integrate the citizens of our city, for example, when presenting our ideas and gathering feedback, or testing newly developed digital prototypes. However, unfortunately, the concrete district is still under construction and so we do not know exactly who will live and work there in the future. This leads to the issue that we can develop concrete digital solutions in a prototypical way, but will probably have to adapt them later or even develop new ones that fit the needs of the residents of the district better. However, the currently developed solutions provide reasonable and concrete ideas primarily for citizens to better understand what might be possible with digitalization to support climate-friendly behavior. Some can also be applied already outside this particular district.

Therefore, for us it is highly relevant to look for many different ways to communicate with the citizens of our city. Similar to other research projects, we also use traditional means, such as a project webpage, printed leaflets, and research papers (which are, however, usually not suited so well for the public). We have organized various events to present our results, such as a symposium, a booth where we could directly talk to people, or hackathons where we developed new solutions directly together with citizens. We also made our digital solutions available, for

* Corresponding author. Phone: +49 631-6800-2248
Email: mailto:frank.elberzhager@iese.fraunhofer.de

DOI: 10.5383/JUSPN.19.01.005

example, as apps or dedicated webpages, and recorded several videos and put them on our YouTube channel [13]. In September 2023, we organized our first event with citizens at the Pfaff district. We presented the main results of the project and discussed our solutions with interested citizens.
Another idea has been to organize concrete results on a separate dedicated webpage [15]. This solution reflects a lightweight and easy-to-explore way that we have developed in the last two and a half years. We call this an ecosystem map, as it reflects our long-term vision for the smart city district of having a digital ecosystem with many digital solutions for individual and connected services. Currently, the map presents four solutions in a compact way and links many further sources for detailed information. We are convinced that providing such information and including citizens and other stakeholders is a highly important step in motivating and taking them along when it comes to sharing ideas on how the digital transformation can support climate-friendly behavior.
The initial version of this paper was published at the 20th International Conference on Mobile Systems and Pervasive Computing [19] and is extended here with more details about the concepts, the evaluation, and future work. The structure of this paper is as follows: We first highlight what the map is, how the conceptual and technical implementation of the map was accomplished, and what initial feedback we collected (Section 2). We furthermore provide an overview of the currently presented four digital solutions and the feedback we have already collected from the public (Section 3). In addition, we share ideas on how to improve the map in the future (Section 4). Our contribution may also influence others with ideas on what kinds of digital solutions could be part of such digital ecosystems.

2. Smart City District Ecosystem Map

2.1. Goal and Idea

One main object of our research project is to present our results to the public [16]. We share digital solutions that support climate-friendly behavior and community-strengthening approaches. This should be done in a way that is easy to understand, is interesting to explore, and provides ways to give feedback. The main idea is to develop a virtual map where people can read the information they are interested in and to have this map serve as an entry point to the journey exploring digital solutions in a smart city district ecosystem. As many people in our city know the district, we decided to create some kind of digital visualization or representation comparable to a "digital twin" of the district to ensure the recognition factor. There are currently mainly individual and small prototypical solutions, but as we are striving towards a larger and connected digital ecosystem, we call it an ecosystem map already (Fig. 2).
The main goal of the map is to inform and ideally convince as many people as possible that using different digital services will be beneficial for acting in a climate-friendly way. With our map, our intention is to provide different kinds of solutions with different goals. For instance, one example provides an overview of new mobility concepts and is a game that can be played by everybody (the MiniLautern game). Another example provided in the map is more suitable for developers of new services and provides a kind of playground for evaluating the effects in the district in a type of simulator (the District Simulator). We provide an overview of all four solutions in Section 3.

2.2. Main Concepts and Development of the Map

When using the app, the starting point represents a high-level view showing the entire district (Fig. 2), i.e., a visualization of the future district with prominent points (such as the famous PFAFF entrance gate). The interaction points placed on the map represent the different digital solutions being developed for the district (see Section 3). Users can dive into the interaction points on the map that are of interest to them and about which they want to know more. By simply zooming in and clicking on the interaction points, they get more information.
Additionally, we created tour guides to help users find their way around the map quickly and easily. There is the tour guide Bernd, who leads the users through the map, sometimes explaining the history of the development of the urban district in addition to how to use the map. He is the starting point for users who want to use the tool. Furthermore, there are four tour guides explaining the four digital solutions. They are based on the same concept as Bernd, but they provide a more detailed look at the solutions presented on the map. Tour guide Svenja talks about the sustainable mobility concepts that are planned to be used in the city district. She also provides information about MiniLautern, a serious game, which aims to have the user create the best sustainable mobility concept. Tour guide Martin is responsible for energy-related topics: e.g., how the district uses sustainable energy concepts and how the people living and working there benefit from this. Fish n' Tipps is an app that is presented in the energy sector and provides tips and tricks based on the user's personal actions, to make them more environmentally sound and climate-friendly. Tour guide Greta presents the community aspect of the district and apps like PfaffFunk. Tour guide Linda acts similar to the others but has a "special" role. She is more focused on the technology side and the District Simulator. This means that she is there to give the user group of technologically interested people a better understanding of the project. The broad mass of the population is probably less interested in this but can also look at the information at any time.
To continuously improve the ecosystem map, the user has the possibility to give feedback (with help from our guide Bernd), with a 5-star rating scheme and the possibility to write a short text about the things they had problems with or would like to see improved.

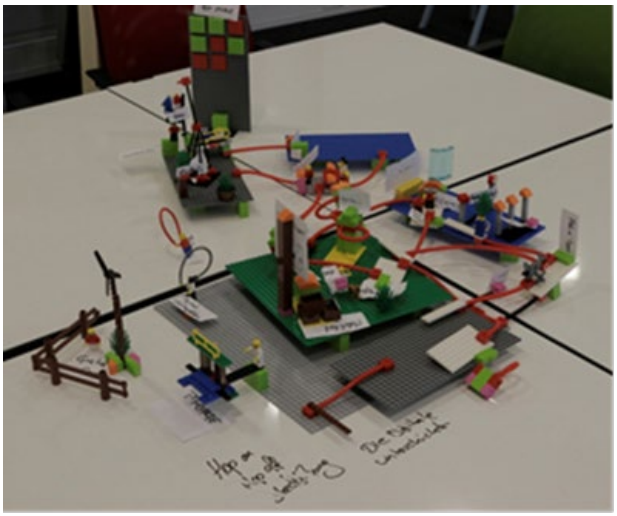

Fig. 1: Basic concept of the map with its layers and connections, which was created in a Lego creativity workshop together with designers and stakeholders

In order to come up with prototypes and the final result, three main steps were taken in the conception process:
(1) Ideation (Lego Creativity Workshop): To get an understanding of layers and the complexity of the map that had to be created, a creativity workshop was held where Lego bricks were used to visualize the connections and dependencies of the different solutions a potential user can find while using the map (Fig. 1). This workshop was based on Lego Serious Play[1], an experience process toolkit for workshops that helps to visualize complex interdependencies and stimulate dialog and reflection about them. Using the information developed in this workshop, the next step was to get an idea of how these layers will look on the screen.

Fig. 2: The smart city district ecosystem map

(2) Combination and Transformation: Initially, the visual representation of the layered map was understood to be a GIS (Geographic Information System) map, i.e., a software-based map that allows geographic information (slopes, water resources, country borders, transportation, etc.) of an area to be viewed separately [9]. The combination of the GIS principle with the results of the creativity workshop formed the concept of our ecosystem map: an interactive visualization that solves the challenge of combining multiple sources and types of information in one map, giving the target audience the freedom to view only the elements that are relevant to them at that moment. This sequencing design pattern, also called progressive disclosure, helps to sustainably reduce user overload by reducing the complexity of the application. This is an important step, which, with the potential addition of new content, is crucial for user-friendly, effective, and efficient use [17].
(3) Visual Design: To prevent the ecosystem map from looking too static and like a "common" map, which might be rather off-putting to the target audience, the different layers were combined in the style of an interactive digital infographic. Objects, assets, and characters are created in a detail-reduced and comic-like style. This style supports the idea that this map is showing the future or a vision of the district. This effect could not have been achieved with the use of realistic-looking assets. All elements on the map, except the characters, were created in 2D based on isometric design principles.
The ecosystem map's main topic areas were translated into digital guides, i.e., non-real people offering information and tours on the map, instead of a separate layer being created on the map for each topic area. The main thematic areas (mobility, energy, community) and the technical layer (neighborhood simulator, platform) are thus accessible at any time and their information content is explained simply and briefly. This combination fulfills the requirement of allowing exploratory tours while at the same time always offering users guidance in case they feel lost.

2.3. Technical Implementation

The map was developed as a single-page web application (SPA) using common web technologies such as HTML, CSS, SVG, and JavaScript. This makes the application usable on most devices without the need to install any additional software; all it requires is a browser. The programming language used for the development was TypeScript, which was transpiled to JavaScript while building the application. Unlike JavaScript, TypeScript has optional static typing. This allows some errors to be detected and avoided at translation time already. The component-based React library was used for the dynamic user interface. Most of the components used are self-developed components with CSS based on styled components. In addition to our own components, we also used existing open-source components for some features. For example, react-zoom-pan-pinch is used for moving the map and react-popper for popovers. In the web application, various state information about already used functions is collected in order to show or hide certain elements of the user interface. These are managed in a Redux store. Thus, the state is centrally available, and the various components can easily access the information contained therein. In addition, the store is persisted in HTML web storage so that the last state can be restored when the web application is reopened.
To get feedback from users, a survey is included in the ecosystem map. Seamless integration of existing survey systems into the map was not possible. Therefore, we implemented a simple survey. Survey results entered by users are sent to an HTTP endpoint and then collected in a document database. An overview of the technical implementation is shown in Fig. 3.

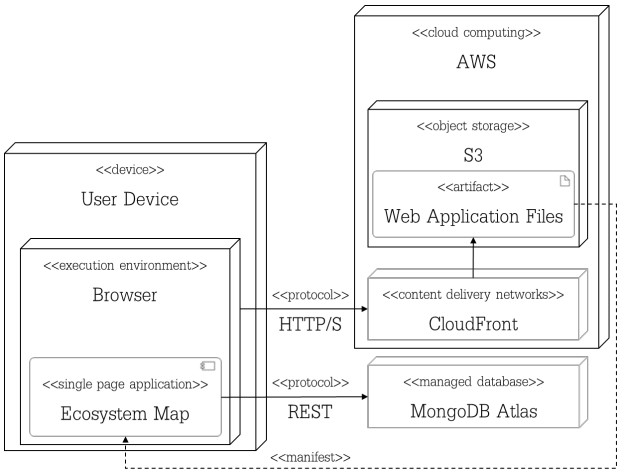

Fig. 3: Technical implementation of the ecosystem map

2.4. Feedback and Evaluation

2.4.1. Method

We evaluated the map in two different ways. First, we did an unsystematic evaluation, meaning we showed the ecosystem map to people without any structured instructions regarding the map or any interview guide. We wanted people to explore the map freely and without bias. Additionally, we chose persons who had no or little knowledge about the project and about Pfaff

[1] https://www.lego.com/de-de/themes/serious-play

and its history. The reason for this way of doing the evaluation was that we wanted feedback without restriction. People were to give us feedback on any aspects of the ecosystem map that stood out to them. Thus, the feedback ranged from formal matters to content and graphical aspects. We performed this kind of evaluation before the launch of the ecosystem map.
The second evaluation was a systematic evaluation in the form of a questionnaire. This questionnaire is integrated into the ecosystem map and went online simultaneously with the launch of the ecosystem map. This gives users of the map the opportunity to express their opinion und rating about the map directly and without changing the interface. The systematic evaluation is split into two areas. On the one hand, users can rate the whole map on the basis of a star rating. On the other hand, they can answer four specific questions about the map with different answer options:

1. Do you like the visualization of the map?
    - Yes
    - No
    - If not, what don't you like?
        - [Text]
2. Are the texts understandable for you?
    - Yes
    - No
    - If not, what is not understandable?
        - [Text]
3. Do you have any suggestions on how we can improve the map?
    - [Text]
4. Do you have comments on the different areas of mobility, energy, community, or the neighborhood simulator?
    - [Text]

2.4.2. Results

The results of the **unsystematic evaluation** had positive, but also negative aspects in all the various categories, like content, formal aspects, graphics, and so on. In the following, we will provide an excerpt from the results.
Content: *Positive*: One positive note was that the user gets a very good introduction from the overall guide Bernd at the beginning of the ecosystem map. He tells the user something about the problem statement and what solutions can look like. Another positive aspect was that the ecosystem map helps in getting to know and understand the solutions as well as providing information about climate-neutral living. Moreover, concerning the systematic evaluation it was remarked that the question "Would you like to answer more questions?" is good for the user, enabling them to choose on their own whether they would like to continue with the questionnaire or not. *Negative*: The ecosystem map helps to understand the solution rather than getting to know the Pfaff area. For this, further information is required. In addition, a few events and contents (e.g., the PfaffHack) that have taken place in the past in connection with the project and have yielded interesting results, especially for the solutions presented on the map, appear to be missing. This corresponds with another note that said that it would be interesting to know what is happening in the Pfaff area and in the project besides these tools. *Suggestions*: One user suggested adding more information about, for example, the approach of the "Reallabor" or events like PfaffHack, e.g., via a link that leads to another website.
Graphics and Presentation: *Positive*: It was said that the presentation of the whole ecosystem map and its details is very colorful and that the map looks like an exciting game board where the user feels like discovering something. The map is packed with many details like construction site hats and bus stops. Another comment was that the animation is "super pretty". Additionally, it was mentioned that the buildings are very well done and that they help with orientation. *Negative*: One negative thing was that the neighborhood simulator button is very large and therefore hides the distinctive old administration building. Furthermore, it was mentioned that the inner courtyards of the buildings give the impression that the user can press a "Play" button, since it looks like a white arrow and a video is running, e.g., on the right side of the border. Another mistake was that on mobile phones, parts of the text were cut off at the beginning. Thus, the user has to slide to the right. *Suggestions*: It was remarked that the area presented on the ecosystem map looks like an independent island. So, it was suggested that it could make sense to show the rest of the city of Kaiserslautern in a shadowy way for localization purposes and to demonstrate that it is part of Kaiserslautern. Furthermore, it was suggested improving the resolution when zooming into the map.
Formal Aspects: *Negative*: There were some spelling mistakes that were noted. In addition, it was remarked that the texts where the tour guides explain the games are quite long. *Suggestions*: One suggestion was that it could be helpful and a nice feature if the guides were to read their texts aloud, with facial animation, which would increase accessibility. Another remark in this context suggested replacing the long texts by animated videos or click dummies.
We took all this feedback, positive as well as negative, and started integrating the suggestions into the map. All this work was done before the launch, so from that moment on, we could fully focus on the systematic evaluation.
The **systematic evaluation** has not generated too much feedback yet, so the result of this evaluation is limited. However, there is a reason for this. Although the ecosystem map has already been launched, it has not yet been promoted too much and has hardly been distributed to the population. Advertising and promoting is one part of future work. Nevertheless, once the map is officially promoted, the systematic evaluation will be the main source for obtaining citizens' and users' opinions about the map.

3. Digital Solutions for a Smart City District Ecosystem

In this section, we present the four digital solutions that are currently presented in the smart city district ecosystem map [20]. Besides demonstrating what kinds of apps and services might be part of the future district ecosystem, we report some experiences we have already made with the solutions. Due to the problem that the current district is largely under construction, we were only able to gather initial feedback and were not able to perform broad evaluations with citizens of the district itself. We also mention the different communication channels we used for the existing solutions in order to ensure that we can reach the public in the best possible way.

3.1. MiniLautern

Idea: The idea of the MiniLautern solution is twofold. First, the game should inform players about new mobility concepts. Second, it should be made clear what implementing new mobility concepts may mean to the public and what positive effects, but also critical consequences are. For example, a district with no cars is positive for quality of life and for the

environment, but makes it difficult to carry things such as shopping goods to the apartments.

Concepts: We used gamification concepts so that the user is interested and curious in exploring and playing the game. The style is rather comic-like; there is a high-score table at the end to provide motivation to replay the game and learn more about the new mobility concepts. Users can play through four rounds and select a mobility measure in each round. After each round, there is direct feedback from virtual residents of the district. Depending on the choice of mobility concept during the four rounds, the player earns virtual points for quality of life, environment, and happiness. The goal is to create the most energy-efficient and best mobility district, i.e., to score as many points as possible (Fig. 4). Based on the selection of the mobility concepts, the map changes and adapts. Finally, the player can give feedback based on a star rating and optionally by answering a questionnaire.

Communication Channels: In the ecosystem map, we explain the idea, concepts, and goals of the game. We provide links to two YouTube videos where (a) the developers of the game provide insights via an interview and (b) a trailer is shown. We directly link the game and provide some example figures. The game was presented to citizens at a symposium and has been introduced in blogs and research publications [10][11]. We also plan to link the game in a physical exhibition currently being developed in the district. Citizens can give feedback via a questionnaire and a star rating after playing the MiniLautern game.

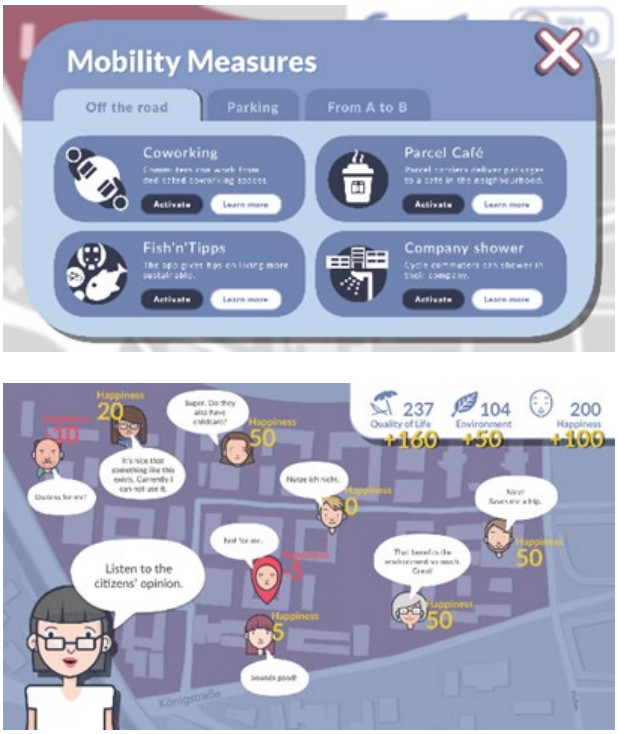

Fig. 4: MiniLautern game with four mobility concepts (top) and overview of the district with residents giving concrete feedback and point scale (bottom)

Experiences and Evaluation: Initial feedback was collected after the first design sprint by confronting four people without a strong technical background with the prototype of MiniLautern. They received an explanation of the basic idea and were guided through the game. They then gave direct feedback while exploring the game on their own. This feedback was consolidated, prioritized, and packaged for further development. After the launch of the game, feedback is collected via two channels. After completing the fourth round, players can provide feedback to the game creators in the form of a short 5-level star rating. As of October 2023, 86 people have given a star rating, with an average of 4.02 stars. Furthermore, users can participate in a short survey with few, which collects feedback on the mobility measures and the game design. 39 players started the questionnaire and 21 of them completed it. The detailed results of the 5-level star rating and of the questionnaire evaluation can be found in [18].

3.2. Fish n' Tipps

Idea: The idea behind the Fish n' Tipps app is to support citizens in engaging in climate-friendly behavior. For this purpose, the app offers a digital assistant that gives tips on how to save energy.

Concepts: We used gamification concepts in this solution, too. Additionally, the concept of personalization was chosen. App users can create a personal avatar in the form of a fish, which provides concrete advice and tips on how to behave in a climate-friendly way. The app is built in an animation style, with fishes and an ocean environment. Tips come either from all app users, who share their own experiences, ideas, alternatives, and tips in the app, or from an Artificial Intelligence that analyzes several types of data and creates tips. Changing habits also plays a major role when it comes to saving energy. Therefore, a playful look & feel and gamification elements were incorporated: The app is designed like a challenge. Points can be earned for creating tips or by participating in challenges. Users can play the challenges together with others or against others. In order to develop a personal feeling for the app and the fish avatar, the fish can be configured individually.

Communication Channels: In the ecosystem map, we explain the idea, concept, and goal of Fish n' Tipps. Furthermore, we provide two YouTube videos where (a) the creation and technical background of the app and (b) the app itself are explained. The game was presented to citizens at a symposium and has been introduced in blogs and a research publication [10][11]. It was also used during a hackathon event.

Experiences and Evaluation: As the app is at an early stage of development, no evaluation has taken place yet.

Fig. 5: **Fish n' Tipps solution**

3.3. PfaffFunk

Idea: The PfaffFunk app serves as a communication app to support the people living in and around the Pfaff district. The aim of the solution is to support the establishment of local communities and provide a way for exchanging information,

chatting, talking, and dating. PfaffFunk promotes exchange within the Pfaff district and strengthens the Pfaff community.
Concepts: News and results from the project are disseminated and contributions from users that are relevant in the context of the climate-neutral smart city district are posted. Users can join different groups or create their own in order to exchange information with others on specific topics. They can use the chat function to talk directly with other users. Additionally, users can offer help or post requests. As a social network for local communities, PfaffFunk thus enables and encourages the building of a community of like-minded people all working together to build a climate-neutral smart city district.
Communication Channels: In the ecosystem map, we explain the idea, concept, and goal of PfaffFunk. The app is available in the Google Play store and the Apple App store and can be downloaded. The game has been presented in blog posts and in a research publication [11]. News shared on the project webpage pop up in the app. Citizens can initiate chats, i.e., they can directly interact with other citizens and with us.
Experiences and Evaluation: A component for the collection of user feedback was integrated into the app that allows two types of feedback, so-called "push" or "pull" feedback. Push feedback is made possible by providing the user with a feedback form to actively express their opinion via emojis. For the pull feedback, the component specifically asks for feedback after events in the application set by the developers. Additionally, the project team regularly publishes articles dealing with current topics of the project. This has established an additional communication channel to interested citizens. For this purpose, statistics were compiled that contrast the number of explicit users, interested users, and posts. These usage statistics show that there is real interest and that the app is accepted within its possible scope.

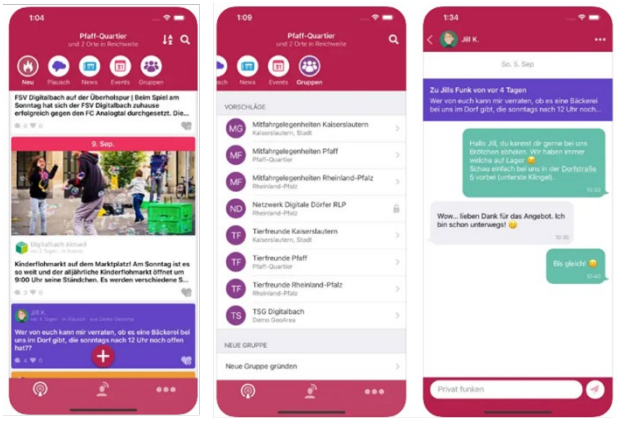

Fig. 6. Impressions of PfaffFunk: news (left), groups (middle), and chat (right)

3.4. District Simulator

Idea: The District Simulator provides a development environment to test prototypical solutions realistically at an early stage. The environment is aimed at citizens with a technical background or companies developing digital solutions for the Pfaff district.
Concept: The virtual district simulator contains a virtual district with scenarios including scripted elements ("person moves") and environment-sensitive services that influence and interact with the virtual world. Users can play through different scenarios in the Pfaff district and get an idea of what life as a resident could be like with all the digital services in the Pfaff district. The simulator runs on a mock platform, which enables developers to quickly try out new ideas or prototype services. The mock platform is an environment intended to support, simplify, and accelerate prototype development. To make the whole thing vivid and understandable, there is a gameboard that simulates the Pfaff district in a form suitable for humans. The gameboard shows what is happening in the Pfaff district, not just as a static snapshot of the world, but by showing what is currently happening in the virtual world. It reflects the current state of the world – every second. There are streets, houses, pedestrian walkways, and streetlights (Fig. 7).
Communication Channels: In the ecosystem map, we explain the idea, concept, and goal of the District Simulator. We also provide a YouTube video where the technical background and the District Simulator itself are explained (i.e., a conference presentation). We provide some example figures. The solution has been presented in research publications [8][12][14] and used at three hackathon events for prototype development.
Experiences and Evaluation: We used different versions of the district simulator at hackathon events where students and technically minded people developed prototypical digital solutions in 24-hour events. We learned that it is necessary to make the start with the technical environment as easy as possible, and created documentation, videos, and a work adventure game for users to learn the basic concepts. Furthermore, developers of the District Simulator were available during the hackathons to support and answer questions. Some of the solutions created during the events managed to use the technical environment [14].

Fig. 7: District Simulator solution

4. Future Development of the Map

Based on the initial feedback already gathered and a collection of our own ideas, we decided to incorporate three main additions.

(1) First of all, some graphical elements should be changed. When we started conceptualizing and developing the map, it was rather unclear which new buildings were to be built or which existing buildings would be modified. As the map should be identified directly as the Pfaff district, we want to update the map as well. Concretely, a wooden multi-level parking garage and an energy center where energy consumption can be controlled and visualized have to be added. Furthermore, in one of the buildings is our new district workshop, where we will have events with citizens in the future, and this should also be shown on the map.

(2) Another issue is that we are currently preparing some final project reports. One will be written in a way that is easy to understand also by people without a technical background. This report (in addition to the initial ICT concept document from 2019) should be made available via our map. However, as this is not a technical solution like the other four presented by the guides right now, we are discussing how to make this available in an appropriate manner. No decision has been made yet. Ideas include using another guide, placing a prominent placeholder directly onto the map and linking the report, or something else.

(3) The third idea is to visualize a future vision of the digital district. As construction progress is not as far advanced as expected some years ago, we only have a very limited implementation of digital solutions to support climate-friendliness in the district., simply because only a very limited number of people are living there. However, we assume that this will change in the future, and we are currently developing future scenarios of what this might look like. We are again using so-called personas, which are representatives of future residents. Based on their perspective, we are thinking about which digital solutions might provide support in which way. We are considering two concrete points in time. One is 2025, when some people might be living there and currently developed solutions in the areas of communication, energy, smart home, or mobility could support them. The other one is 2040. Here, we can think more freely about how technology might evolve and what could theoretically be possible. Independent of the concrete scenarios, we are currently thinking about how to visualize this in the ecosystem map. One idea is to have some kind of slider that changes between the current view and the future, potentially with some intermediate steps where changes happen in the district. Another idea is for Bernd, our main guide, to inform the users that another layer exists and to guide them to the future. A third idea might be to place a construction sign on the current map that provides information about the future map. Independent of the implementation, the future map should be much livelier; i.e., it should show people should walking around, bicycles being used by residents, dogs being walked, etc. Furthermore, it should be more greenish; e.g., there should be green spaces in combination with photovoltaics on the roofs of the buildings or plants on the façade of the buildings. Another idea is clicking on the virtual people moving around in the district and seeing the district with all the changes directly from their perspective. However, this might cause much more implementation effort than available in the course of this project. Finally, topics such as education or health, which did not play a large role in this research project, but are important in the future district, could also be addressed with digital solutions that can be visualized on the map.

Besides these three bigger changes, there is also some bug fixing, performance optimization, and other small changes going on right now. We also would like to use the map to directly point to our YouTube channel and provide an overview of existing videos. However, how to include this in the map is still under discussion. We presented the map at our district workshop in September 2023 to share the project results, and therefore expect more structured feedback from citizens in the near future when more events will be held. This might also lead to new ideas on how digital solutions can be developed and then shown on the map, too. Current ideas go into the direction of waste management or heavy rain events. However, we expect many more ideas and are also curious as to how the district will continue to evolve.

5. Conclusion

In this paper, we presented a virtual map of a smart city district that provides information about four digital solutions we created for a future smart city district digital ecosystem. This ecosystem map is meant as an entry point for citizens to explore the currently available digital solutions. We used several communication channels to inform citizens and gather feedback from them wherever possible. We are convinced that the key to success is broad communication with the public, so we need to find ways to "translate" research results in order to make it easy for the public to understand and consume them. The map is our solution. We plan to provide more videos and events to foster communication. In addition, we are currently implementing a room in a building in the district that may serve as a future meeting point.

Furthermore, we described the four digital solutions of the future smart city district that we have developed so far. Based on the current limited feedback, we believe that such kinds of solutions are helpful to support climate-friendly behavior. We plan to develop them further as the district evolves. In addition, we presented three ideas of how to further develop the map. New solutions could be created and existing ones adapted once people actually live and work in the district in the future. The map can then also continue to be updated and serve as a digital map that provides guidance on how to use the available solutions.

Acknowledgments

The research described in this paper was performed in the EnStadt:Pfaff project (grant no. 03SBE112D and 03SBE112G) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry of Education and Research (BMBF). We thank Sonnhild Namingha for proofreading.

References

[1] Haktanir E et al. A State of the Art Literature Review on Digital Transformation. In: Kahraman C, Haktanir E (Ed), Intelligent Systems in Digital Transformation: Theory and Applications. Springer Nature Switzerland, 2023, pp. 3-31.

[2] Neirotti P et al. Current trends in Smart City initiatives: Some stylised facts. Cities 2014;38:25-36.

[3] Mashau NL, Kroeze JH, Howard GR. Key Factors for Assessing Small and Rural Municipalities' Readiness for Smart City Implementation. Smart Cities 2022;5(4):1742-1751.

[4] Lea R. Smart Cities: An Overview of the Technology Trends Driving Smart Cities. Working Paper. IEEE 2017. Available: https://www.ieee.org/content/dam/ieee-org/ieee/web/org/about/corporate/ieee-industry-advisory-board/ieee-smart-cities-trend-paper-2017.pdf

[5] Sapture P, Ramadhan A. Smart Building Trend, Role, and Position: A Systematic Literature Review. International Journal of Reconfigurable and Embedded Systems 2023;12(1): 29-41.

[6] Wang H et al. Digital twin-supported Smart City: Status, Challenges and Future Research Directions. Expert Systems with Applications 2023; 217:119504.

[7] Teimoori Z, Yassine A. A Review on Intelligent Energy Management Systems for Future Electric Vehicle Transportation. Sustainability (Switzerland) 2022; 14 (21):14100.

[8] Ajdari A et al. Smart City District Simulator – How we Made a Virtual Smart City District Come Alive. Proceedings of the 8th International Conference on Connected Smart Cities. Lisbon, Portugal, 2022.

[9] Audet RH, Gerald LA. Geographic Information Systems: Implications for Problem Solving. Journal of Research in Science Teaching 1996; 33(1): 21-45.

[10] Elberzhager F. "EnStadt:Pfaff"-Fachsymposium: Präsentation des aktuellen Projektfortschritts für ein smartes Quartier der Zukunft. Fraunhofer-Blog 21.10.2021. Available: https://www.iese.fraunhofer.de/blog/fachsymposium-smartes-quartier/

[11] Elberzhager F et al. Towards a Digital Ecosystem for a Smart City District: Procedure, Results, and Lessons Learned. Smart Cities 2021; 4(2):686-716.

[12] Elberzhager F et al. On the Roads Towards a Smart Urban District Supported by a Mock Platform. Proceedings of the IADIS 7th International Conference Connected Smart Cities 2021.

[13] Elberzhager F, Mennig P, Stüpfert P. Building a YouTube Channel for Science Communication. In: Kotsis G et al. (Ed), Database and Expert Systems Applications – DEXA 2022 Workshops, Communications in Computer and Information Science 2022;1633.

[14] Neuschwander P et al. Using a Smart City District Simulator to Test New Digital Services. Connected Smart Cities 2023. Available: https://mccsis.org/wp-content/uploads/2023/07/CSC2023_F_023.pdf

[15] Elberzhager F, Späth K, Storck S. Visualization Concepts of a Digital Ecosystem to Increase Understandability. Connected Smart Cities 2021, ICT.

[16] Kotsis G et al. Database and Expert Systems Applications - DEXA 2022 Workshops. 33rd International Conference, DEXA 2022, Vienna, Austria, August 22–24, 2022, Proceedings, Communications in Computer and Information Science 2022: 1633.

[17] Casian O, Railean A. Developing Graphical User Interfaces Using Human-Computer Interaction Principles. 4th International Conference "Telecommunications, Electronics and Informatics, 2012.

[18] Elberzhager F, Mennig P, Behrendt-Henn Y. Informing on Climate-Friendly Novel Mobility Measures: Development of the Serious Game "MiniLautern" and Analysis of Player Feedback. 19th International Conference on e-Science (e-Science), Limassol, Cyprus, IEEE, 2023, pp. 1-8.

[19] Elberzhager F, Schmitt A, Schweitzer S, Storck, S. An Ecosystem Map to Communicate Digital Solutions Supporting a Climate-Friendly Smart City District. Procedia Computer Science 2023; 224:114-121.

[20] Pfaff Landkarte (in German), available: https://www.pfaff-landkarte.de/