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Illustration of design of digital water quality monitoring services for smart cities

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Abstract: Water quality monitoring is important in smart city planning for managing the water resources. In the smart city, more data is being collected. In terms of data related to water quality, many data sources such as smart sensors, attached to water quality monitoring system have been continuously collecting a significant amount of data. The potential of collected data from these sources holds no value for smart cities, unless it is being used to provide digital services such as information about clean and safe drinking water, swimming, fishing, domestic uses and also for water reuse. However, the knowledge on how to utilize water quality data for the benefits of smart city residents is limited. So, in this paper, I propose a digital water quality monitoring services for smart city residents. I explore this proposition through a design study engaging smart city residents, service designers and developers of water quality monitoring system. As a result, a service blueprint is presented as an illustration of how such services can be designed to provide water quality information for different activities. The aim of the study is to illustrate how opportunities of water quality monitoring system can be explored for smart cities. The intent of the study is that the results are useful to designers and researchers in designing and developing digital water quality monitoring service in smart cities.

Keywords: Water quality monitoring, smart city, service design, service blueprint

1 Introduction

In the world, more people live in cities as compared to that of rural areas [1]. According to Destouni et al. (2017), recent studies have shown that many water areas are not safe, and some have even deteriorated due to human activities such as dumping of chemicals from factories, discharge of untreated raw sewage from household and factories, human littering of plastic, glass and other wastes to water bodies. As per Mounce (2020), there is an increasing pressure on water resources due to the increase in population growth, urbanization, industrialization and climate change, so consequent requisite of water management is necessary for smart cities. Smart city is a city developed by the integration of the Internet of Things (IoT), Information and Communication Technologies (ICT) for collecting data. The collected data is interpreted and analyzed to efficiently and sustainably manage resources, urban systems, urban facilities, and community services (Hammad et al., 2021). In smart cities, IoT technology enabled collection of water related data from various sources such as smart sensors, smart meters, remote sensing that could be used for the management of water resources.

Water quality monitoring should be at the heart of all smart city planning (Mohanty et al., 2016). The water quality data is accumulating in a faster speed with the advancement in the monitoring techniques, but it holds no value in itself unless it is used efficiently (Mounce, 2020). The real-time information on water quality is increasingly demanded by decision-makers in various fields, from recreation to human health

(Keeler et al., 2012). The water quality data can be used to provide alert warnings to the smart city residents for making an efficient and speedy decision regarding the water usage in need of time. Also, the real time information provided by the digital water quality monitoring service can be used for conservation practices such as water reuse and evidence-based policy practice or payment programs (Yan et al., 2016). Water quality data might also result in the coincidental delivery of other services, such as habitat supporting biodiversity, swimming, tourism, commercial and recreational fishing (Butler et al., 2012)

The water quality monitoring data effectively acts as the data source to manage a city's assets for sustainability, resilience, and livability (Chen and Han, 2018). But there is little research on how water quality monitoring services can contribute to the sustainable development of smart cities using the water quality data (Paska, 2018). Also, Gao (2017, p.224) concluded that "there is a lack of integrated real-time big data-based water evaluation and monitor environments for smart cities to support dynamic water quality evaluation, monitor, and supervision management". Despite collecting large data related to water quality, few services are designed to be digital (Stillman et al., 2020). Also, there is a need to aid the decision-making process to make the best possible use of the water quality data that is available (Mounce, 2020). As per the words of Keeler et al. (2012) water quality data is an important contributor for informing different acitivities such as access to clean and safe drinking water, fishing, swimming, domestic uses and also for water reuse. Companies like Nokia and Huawei are conducting research on how water quality monitoring data can be used incorporate services for smart cities (Paska, 2018). However, most of the data related to water quality are not used efficiently for designing digital water quality services. This is mainly due to the significant challenge in using the raw data to yield digital water service operations (Stillman et al., 2020).

Hence, further research on designing services using water quality data becomes relevant. As per Stickdorn et al. (2018), service design is one of the best available methods to innovate or to improve services to make them more useful, usable and desirable to the users. Thus, service design methods can be used to leverage and refine existing knowledge of water quality data collected by water quality monitoring system. This study will pave a way to explore how to design digital water quality monitoring services for smart cities. Thus, my research question was

"How can digital water quality monitoring services be designed for the smart cities."

The aim of the study is to illustrate how opportunities of water quality monitoring system can be explored for smart cities. This study was conducted to explore how water quality monitoring services can be designed so that they can potentially contribute to the sustainable development of smart cities. The exploration was done through a design study using service design methods such as user journey map and resulted in a service blueprint.The service blueprint illustrates how the design of digital water quality monitoring services can be used to provide information about clean and safe drinking water, agriculture, fishing, domestic uses and also water reuse to smart city residents.The study was done in the context of research project named catfish which is real time water quality monitoring system. It is an IoT experimentation system consisting of interconnected drones for inspecting freshwater and saline water bodies in low and medium depth.

2. Related Literature.

This section deals with the relevant literature related to research question and problem space. This sections explain in detail the key terminologies which are essential to carry out the research

2.1 Water Quality Monitoring in Smart Cities

A smart city is defined as "an innovative city that uses information and communication technologies and other means to improve quality of life, the efficiency of urban operations and services, and competitiveness

while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects"(Mohanty et al., 2016, p.61). It can be considered as service organization with the residents as the customers, providing services to its residents (Kuchta, 2014). A smart city should be a creative, sustainable area that improves the quality of life, creates a friendlier environment and stronger prospects of economic development. The infrastructure of a city is any basic physical component of the city, such as roads, clean water, electricity, buildings, sewage, bridges, that make the city and its inhabitants operate. When the physical infrastructure such as waste management system, water supply system, recreational facilities, of the smart city combined with ICT infrastructure, makes the infrastructure of the smart city a smart one. The ICT infrastructure includes fiber optics, Wi-Fi networks, and wireless hotspots, sensors, firmware, software, service-oriented information systems. Thus, the back end of the smart infrastructure is the ICT infrastructure, which makes the physical infrastructure "smart." (Mohanty et al., 2016). Vast amounts of data, thus collected in the smart cities are available and could be used to create intelligent solutions within related areas of e-services application (Kuchta, 2014).

Maintaining the water quality in good condition will benefit residents of the smart cities. For the time being, water quality monitoring systems using IoT, ICT, sensor, and wireless technologies have been evolving to understand and mitigate water-related risks such as health problems due to bad quality of water.

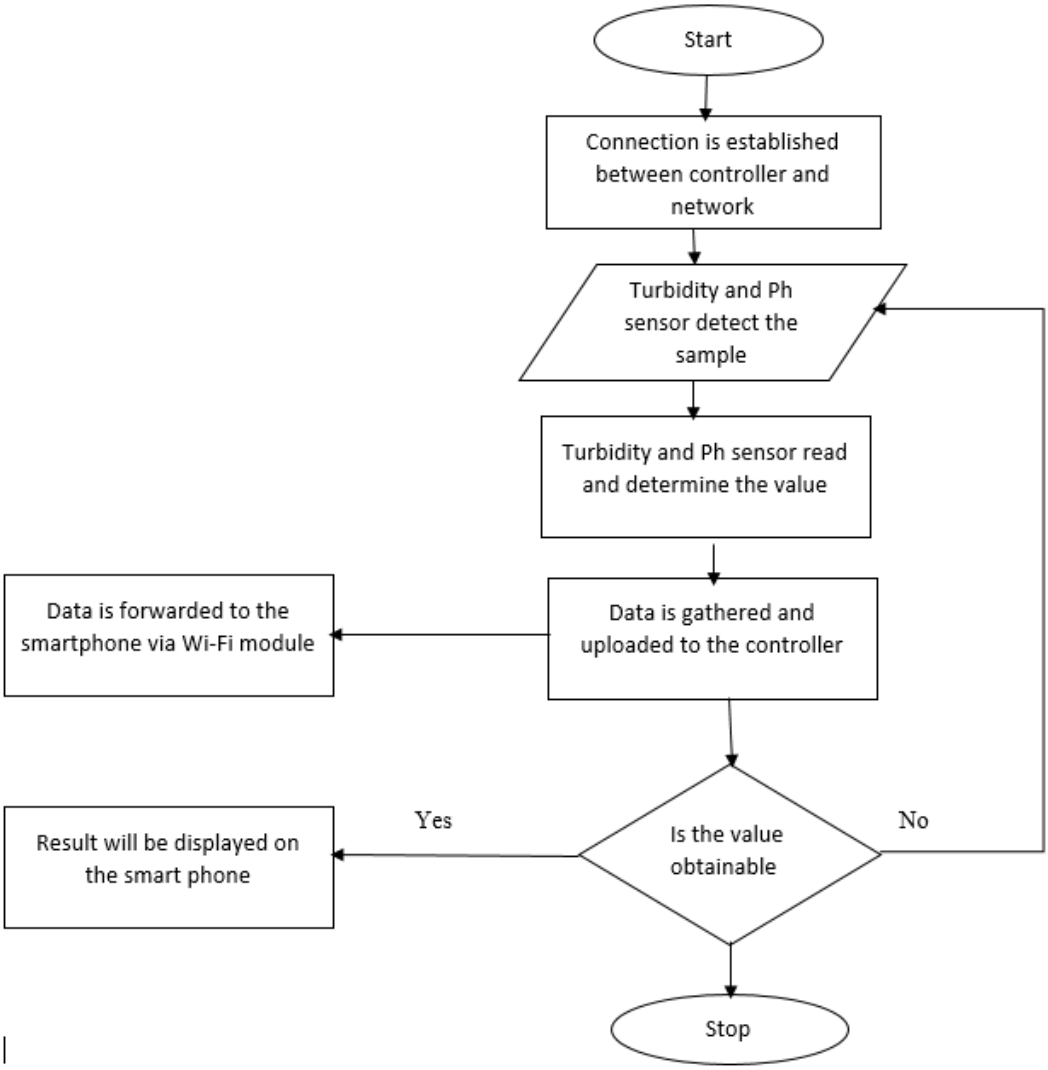

Figure 1. The Flowchart of IoT Water Monitoring System in smart city (Mohd et al., 2020)

Mohd et al. (2020) presented a flow chart for real-time water quality monitoring system in smart city as shown in figure 1. As per the flowchart, initially the user needs to establish a network between the microcontroller and the smartphone via Wi-Fi. Once microcontroller is connected to the smartphone, then water samples are collected by using a turbidity sensor and pH sensor. Turbidity refers to the cloudiness of a fluid caused by the increased number of very tiny particles which, individually, is invisible to us. Whereas pH indicates whether water is acidic or alkaline. Both Ph and turbidity sensor read and determine value. Then, the determined value is sent as an analog signal which is converted into a digital signal and send to the microcontroller, which analyses and process data. The processed water quality data is sent to the smartphone using Wi-Fi module. The Wi-Fi module has a powerful on-board processing and storage capability that allows it to be integrated with the sensors. If the connection is not established between the smartphone and the microcontroller, the water quality data will not be displayed, even though the sensor probes were in the water samples because no connection has been made. In the discussed flowchart of real-time water quality monitoring system there were only two water quality parameters(Ph and turbidity) collected , but the water quality monitoring system can collect more water quality parameters in real time by attaching more sensors to it (Chen and Han, 2018). Mounce (2020) stated that increasing amounts of water quality data are only of real value if this data is ultimately used to provide digital services to the smart city residents.

Chowdhury et al. (2021) explained the following 1.Generativity of digital technology stimulates oppertunities for digital services. 2. Generativity is the property of enabling novel use of digital technologies to generate or produce new outcomes. 3. The digital technologies have the property to replicate the digital contents such as collected data from the sensors. 4. For example,The data collected from connected vehicles can be replicated and continuously used for the services, such as sending monthly reports to a vehicle owner about health status of the vehicle. Similarly data is also being collected by the various sensors attached to the water quality monitoring system for determining the quality of water (Chen and Han, 2018). By employing appropriate tools, analytics, and workflows in water related services, make the best use of the data (Stillman et al., 2020), and leverage them to inform smart city residents about different activities such as swimming, access to clean drinking water, fishing and also for water reuse based on water quality data (Keeler et al., 2012).

2.2 Service Design

A service is defined as applying competencies (knowledge and skills) by one entity for the benefit of another (Vargo and Lusch, 2006). Design is a structured creative process (Ulrich and Eppinger, 1995) for problem-solving where problems can be decomposed into smaller units before it is solved (Simon, 1969). Krippendorff (2006) describes the design as a "human-centered" activity in contrast to a technology-centered design focusing on functionality. There is more value to service design beyond visualizing a product or service. It is the process of finding out what a product or service is going to be, what it is going to do, how it is going to function, how it is going to look, and what it is going to say (Steen et al., 2011; Omar, 2014). Service design is human-centred, collaborative, iterative, sequential, real and holistic (Stickdorn et al., 2018). Service design serves as a communication channel with users, fosters a creative environment for the ideation and development of new services, gets an in-depth understanding of the designs and delivers better customer experience(Steen et al., 2011; Omar, 2014). In service design, there are various tools from various fields and disciplines that can be used to achieve innovative results (Yu and Sangiorgi, 2018). Alves and Nunes identified more than 160 design thinking tools and proposed a set of visualization that can be mapped in six dimensions: "who/what, how many, where, when, how, and why" (Alves and Nunes, 2013, p. 215).

The collaboration of a service provider with the customers is commonly referred to as co-creation (Lusch et al., 2007). In service-dominant(S-D) logic, a service value is jointly cocreated by service providers and customers through interactions and uniquely determined by customers' use experiences (Vargo and Lusch, 2008). Customer participation refers to the degree of customer involvement in providing information and

feedback on specific issues related to new service (Ye and Kankanhalli, 2020).The customer participation can increase the density of important resources (e.g., latent customer needs, preference, and contextual usage knowledge) (Storey and Larbig, 2018), that the service providers can integrate to the service for better service performance by employing practices such as inviting customers to comment or to provide ratings about the service (Ye and Kankanhalli, 2020).

2.3 Service Blueprint

Service design helps to map and visualize the end-to-end experience of the user and therey creating superior service experiences results (Yu and Sangiorgi, 2018). The user journey map help to visualize the user experience and can also act as speculative tool that can be used to imagine and ideate what a user might see and do in a future experience while designing a new service. User journey map will always highlight the frontstage of the user experience, whereas service blueprint exposes the frontstage as well as the backstage process of a service. The backstage process of the service is usually invisible to the user and followed by the support process by the external people (Shostack 1982, 1984). As compared to other process-oriented design techniques, service blueprints are customer-focused, allowing the visualization of the service process, points of customer contact, and the physical evidence associated with services from the customer's perspective (Bitner, Ostrom, and Morgan, 2008). Thus, the service blueprint explains in a detailed way how a service is being triggered by the user and how service provider orchestrates the need of the customer internally (Stickdorn et al., 2018). The results of the blueprints not only provide visual representation of a service,but alo serves as a focal point for later refinements or last-minute changes for developing new services, improving existing services, and expediting multi-disciplined communication in support of customer-focused solutions (Bitner et al., 2008). Thus, It act as common platform for customers, employees, and managers to participate in the service design process before developing it. It also disclose all of the touchpoints that are critical in satisfying the customer needs and helps in identifying likely points of service failure (Shostack, 1984).

3 Research Approach

The research approach I choose for my study was design science research approach to explore opportunities of water quality monitoring system for smart cities. It is a problem-solving paradigm which "seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design implementation, management, and use of information systems can be effectively and efficiently accomplished" (Hevner and Chatterjee, 2010, p.11). I choose this approach to explore new opportunities in water quality monitoring system for smart cities in a unique or innovative way by following the guidelines from Hevner et al. (2004) for designing and evaluating artifacts.

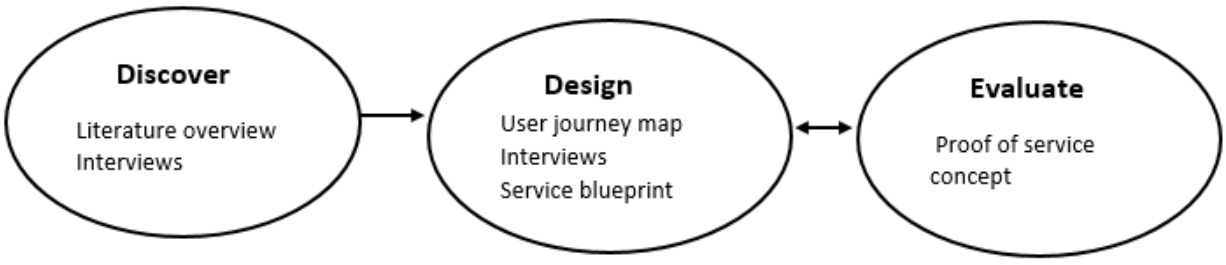

Figure 2: Design cycle adapted from(Evenson and Dubberly,2010)

I organize the study in three-stages - Discover, Design and Evualate adapted from integrated service design process, which is people centric and can be altered according to the design challenge (Evenson and Dubberly, 2010).The Discover stage was a problem identification phase that helped to understand the business environment (smart city) where the problem exists. In this stage, I conducted the literature overview to know past knowledge of the research project from the literature about water quality monitoring systems in smart cities, service design and service blueprint. This knowledge was used as an input for designing the solutions. Then, semi-structured interviews were conducted with smart city resident to identify the problems related to water quality in their smart city, where they lives. In the design stage, a research based current state user journey map of smart city resident was developed based on the insights gathered from the interviews with smart city residents. The interviews with developers of water quality monitoring system helped to know about the water quality data collected by the various sensors in water quality monitoring system, that can be used for the benefit of smart cities. This was followed by the interviews with service designer, that gave insights about how can water quality monitoring services be designed to inform smart city residents about different water related activities. The insights thus gained by all the interviews were used to design service blueprint as illustration of digital water quality monitoring service for smart city residents. In the Evaluate stage, I employed proof of service concept method for validating the illustrated service blueprint by the public citizens using three validation criteria. By doing so, it helped me to know whether the designed service blueprint is feasible and flexible for the development of the service in the real world.

3.1 Research Context

The study was conducted in a project named catfish which is real time water quality monitoring system. It is being developed by innovation lab, at Halmstad University that can be used as a unit for monitoring quality of water in rivers,lakes and seas.The main components of catfish are cat (unmanned boat/systems of system), fish (underwater drone), bird (flying drone) and soul (intelligent platform). The cat carries out functions as to perceiving, sensing and measuring, navigating and moving, communicating, producing and storing energy. While the fish is capable of sensing, perceiving, sampling, navigating and moving in marine and fresh bodies of water such as springs, rivers, lakes, and dams and the bird will senses and measures the air quality, navigate and move, perceive and transport water samples. Moreover, soul does data processing, data storing, monitoring and controlling systems. The project is under development process where my task was to explore the oppertunities in the catfish for the providing digital services such as information about different water related activities to the residents of smart cities.

4. Research Methodology

This section explains the various design science research methods explained in the research approach for designing digital water quality monitoring services for the residents of smart cities.

4.1 Literature Overview

The purpose of literature ovreview was to explore and understand the context in which the design problem was framed. It helped to understand what was already known in the research area like existing water quality monitoring in smart city, the main concepts and theories such as service design, co creation, which was used in the study (Hanington and Martin, 2012). Also, it enabled to identify research gap in the existing literature, so that this study can contribute new knowledge. The information was collected from different databases such as Google Scholar, Scopus, and Science direct using keywords smart city, water quality monitoring in smart city, service design, co creation, customer participation in service design, monitoring services.

4.2 Semi - Structured Interviews

The qualitative interview is a data-gathering tool in qualitative research (Myers and Newman,2007). In the study, interviews were planned with smart city residents, developers of water quality monitoring system and lastly with the service designers. All the interviews were planned as semi-structured, where the questions were formulated to start from a general level moving towards more defined areas. The main reason for selecting semi-structured interviews was to have the flexibility to probe more into specific areas of context and to allow the interviewees to continue the conversations. Participants were contacted intially through email and informed about the research project before the interview. Due to covid situation most of the interviews were conducted via zoom and Microsoft teams. However, virtual interviews had some benefits such as inexpensive, minimization of ecological resources used by travel.The duration of the interviews was planned to be thirty minutes. All the interviews were recorded after asking interviewees for their consent.This helped to analyze the collected data at a later date and also enables to quote the words of the interviewee directly.

The residents included in the interview were two residents living in the smart city named Shobha city, India and the remaining one living in Cleo county, India. All the residents were living in the smart city for more than two years and hence they were more familiar with the infrastructure of the smart city. The purpose of interviews with residents was to find about the main problems and concerns related to water resources that they encounter while living in the smart city. It also enabled to investigate how currently residents of smart cities were monitoring water quality, how they feel about it, water quality related problems faced by them, and what kinds of change in water quality services can be applied, that was used for designing for smart city. The developers of water quality monitoring system , who were engaged in the interview in my study were catfish team, where each team consist of two members. The purpose of interviewing with the catfish team aided to understand about the data available in digital water quality monitoring system and the linkage of such data with the different ecosystem services. This knowledge was used to provide a solution to water quality related problems faced by the smart city residents. One of the service designers, who engaged in the interview method has 2 years of experience in startup company providing home support monitoring solutions to elderly and disabled people. The interviews with him helped to understand the various challenges and considerations involved in designing monitoring services which was useful in my study. The other service designer is working in the game industry for 3 years and was specialized in designing the various elements of the game such as setting, rules, story flow, character interfaces, vehicles and modes of play. Interviews helped to know various design methods employed in the game design which enhances the gaming experience of player that contributed to my study. Table 1 shows the details of the interview participants. Participant ID was given to each participant engaged in the study to maintain anonymity.

Participant ID	Role of interview participants	Gender	Follow-up Id
R1	Smart city resident	Male	
R2	Smart city resident	Female	R2a
R3	Smart city resident	Female	R3a
A1, A2	Catfish team (Autonomy)	2Males	
E1, E2	Catfish team (Environmental)	Female	E1a, E2a
S1, S2	Catfish team (Sensor)	1Male and 1 Female	
D1	Service designer	Male	
D2	Service designer	Male	

Table 1. Details of interview participants

After the interviews, when I reflected what I heard from the interviewees and carried out preliminary interview data analysis, I found there need some clarification on missing, incomplete and confusing statements. So, I conducted some follow up interviews with the participants who was more openminded during interview and labelled them with follow-up id in the table 1. I also shared the user journey map with them, which was developed during preliminary interview data analysis. This enabled energize the interview process and in turn lead to high-quality data as per word of Bischof et al. (2011) which really strengthened my study.

4.3 User Journey Map

A user journey map is a visualization of the experiences of users while interacting with a product or service, where each moment is individually analyzed for improvement (Hanington and Martin, 2012). In my study, the experiences of the smart city resident were mapped from the interviews conducted in an order and thus a story was developed about an user's actions, feelings, perceptions which included the positive and negative moments as he or she interacts with a service over a period of time. By doing so, it helped to identify various touchpoints encountered by the smart city residents for the better understanding of their pains and gains involved in accessing water related services in smart city. In the study, research based current-state user journey maps were employed inspired by Stickdorn et al. (2018). The purpose of research based current-state user journey map of a smart city resident was to inform the author about the existing water quality related problems faced by smart city residents in accessing water related activities. The major problems identified were the health issues due to poor quality of water, lack of access to real time water quality information and inability to take appropriate decision to use water or not at right time. The user journey map also informed the need of oppertunties to reduce the painponts of smart city resident.Thus, research based current-state user journey map revealed the gaps in the existing experience in accessing water related activity and also enabled to identify opportunities to improve the services using water quality monitoring system.

4.4 Empirical Data Analysis

All the interviews were recorded and transcribed into digital text file by the author itself. Analysis was done by reading the transcribed text several times to select the data relevant to the study among the large chunk of unstructured data of different interviewees. The irrelevant data were discarded in the study. Also, more scurtinizing was done by the author by going back to the research question and aligning the selected empirical material as per the question to achieve the research objective. Then, the selected empirical material was hightlighted in three different colours,where each colour indicate the intervieweees quotes, that can be used for the three different stages (discover, design and evaulate) of design process. When analyzing data, the author not only described what interviewee told but also interpreted (Gray, 2016), which guided in designing digital water quality monitoring services to inform the residents of smart cities about different activities such as clean drinking water, fishing, agriculture and water reuse. For eg: The empirical material collected from the interviews with three smart city residents was analysed, intrepreted and then motivated to develop a research based current state user journey map. The visualisation of whole journey of the smart city resident was analysed from the intial contact to end use, aided to identify the various pains points and the emotions in the current experience in accessing water related activity such as swimming in smart city. Thus, this analysis enabled the author to identify the water quality related problems faced by smart city residents, where the oppertunities of water quality monitoring system can be applied to solve the problems.

4.5 Proof of Concept

The purpose of proof of concept was to validate the illustrated service blueprints of digital water quality monitoring services for smart cities from the very early stages of the innovation process inorder to avoid the failure of the digital service after its implementation (Passarelli et al., 2020).In the study, three public citizens were participated in the validation method virtually using zoom application, where each of validation process lasted for 30 minutes. Firstly, author gave an explanation about the developed service blueprint and its workflow along with its image. Some time were alloted for clarifying citizen's doubts related to designed servic blueprint. Then, the citizens were introduced with the following validation criteria to validate the service blueprint.

- operational feasibility: The illustrated service blueprint aimed to solve the water quality related problems in smart cities by providing solutions to the smart city residents. Kostopoulos et al. (2012) explained that a successful service blueprint process will enable the service provider to offer standardized solutions to customers. Then only the service blueprint will be feasible for development in real world setting (smart city). This criterion of operational feasibility measures how well service blueprint of digital water quality monitoring services solves the water quality related problems of smart city residents and examines how well it integrate into the daily practice for smart city residents in accessing water related activities.
- flexibility: The designed service blueprint illustrates many activities, that a smart city resident can perform to avail the services offered by digital water quality monitoring services. Also, design needs to be updated from time to time and also be capable for customisation to meet the customer's need. So according to (Kostopoulos et al., 2012) a service blueprint should be flexible enough to add more services or improvements to satisfy the customer's individual need. In the illustrated service blueprint, more activities can be added to improve the user experience of the smart city resident.

The public citizens started sharing their ideas, concerns,suggesstions and perceptions for the improvement of the designed service blueprint. This method helped to validate the feasability and flexibility of the developed service blueprint, as it represents a small-scale visualization of digital water quality monitoring services for smart city.

4.6 Ethical Considerations

The interviews were constructed with an ethical perspective and intended to maintain the integrity and well-being of the participants as encouraged by Bryman and Bell (2011). Ethical perspectives helped to ensure that impact of interviews was for the good of all people and does no harm. Before the interview, some ethical considerations such as informed consent, dedicated chatroom to collect and process interview data for protecting privacy of the interviewee, anonymity, measures of confidentiality were followed to build confidence and trust between the interviewer and interviewee. The interviewees were given option to stop the interview at any time for personal matters, they were also informed about the possibility to decline recording, to refuse to be a part of the study which they should be fully aware of or not to answer any questions they felt inappropriate. The study also followed GDPR regulations, for example no names of either the participant was not mentioned in the study and the interviewee was labelled with participant ID to ensure anonymity. All the information and results related to the participants in the study were kept confidential which they were informed of and only minimal information about the interviewees were disclosed in the study.

5. Designing Digital Water Quality Monitoring Service for Smart City

The design process of digital water quality monitoring service for a smart city was employed in three stages: Discover, Design and Evaluate

5.1 Discover

This stage started with the interviews with smart city residents to discover relevant data, which helped to gain insights about water quality related problems faced by them and need of water quality monitoring service in smart city. All the participants responded positively towards the importance of water quality monitoring services required to be established in their smart city. They conveyed the message that there was no proper water quality checking system available in the smart city where they are living. Some of the participants were aware of the benefits and necessity of such systems and expressed some instances, which is conveyed by the quotes below.

"*Yes, very much needed especially here. I feel there is no proper water quality checking system available here."* R2

"I think, it will help to understand the quality of water what we are using for all our needs." R3

"It will help to keep the water body free from pollution." R1

The following quotes of smart city resident illustrated the water quality related problems faced by them. If the quality of the water is poor, it will cause a lot of issues. One of such health-related problem is skin irritation especially among kids while swimming. In some of the instances they had to postpone all their water related fun activities what they already planned. In nutshell, it will destroy the enjoyment and fun of the people engaged in recreational activities.

"One weekend, I planned to have some fun activities in water with my friends, but unfortunately we often need to come back from water by canceling all our fun when we see so many green colored algae in water. We felt very distressed on that day." R3

"*Yeah, I remember, my kids used to swim daily during summer in the swimming pool. But few years ago, he got some skin rashes after swimming. After that I was little worried in sending kids for swimming. But what to do? How long can I restrict my kids from swimming?"* R2

The quotes below revealed that it is difficult for them to know quality of water in advance. Currently there is no water quality monitoring system in smart city where study was conducted. The smart city residents are taking water samples to lab for checking the quality of water. Moreover, it was a time-consuming process and it was expensive also. Normally, they need to take water samples from water bodies in a separate bottle, need to take it to lab for testing, after that they must wait for few days to get the results. The whole process of checking water quality was a bit difficult and time-consuming process for smart city resident. So, people rarely do this kind of testing, they will do only when they really feel to do it. Also, if resident is going for swimming every day, it will be difficult for them to collect the samples from that water resources and test in the lab to check the quality of water.

Currently, we don't have an option. So, we need to take samples and we get to some labs for testing. We have only that option." R2a

"*If we are going for a swimming every day, we cannot go to destination beforehand to collect samples and give it to the lab to test every day. It is practically impossible and quite expensive."* R2a

"We don't have any other option. we are forced to use that water until we get the results from the lab even if it is 24 hours. So, we do it rarely only in emergency" R1a

Also, People liked to know the status of water quality before planning recreational activities in water as well as for domestic use. It is more reflected when I enquired about their suggestions for avoiding such issues, the residents responded in a way which is quoted below. They wanted to know information in advance before planning or using water to take a decision whether to go ahead with plan or not.

"I think it is always good to have some banners with some information about the condition of water especially if it is bad in the entrance of lake or river so that people like me will surely avoid going into water anymore." R3

"Some type of communication stating that there are some issues with water, and it should be avoided for certain use will surely help us to protect ourselves from bad effects of water. Also, it would help us to decide whether we need to use that water or not." R1

From the above statement, it conveys that that there is lack of knowledge for the smart city residents about the information of the quality of the water bodies. If they are aware of the such information, they can make wiser decisions at right time rather than making themselves vulnerable to its ill effects caused due to the poor quality of water. The access to water quality information by the smart city residents makes them able to take appropriate decision at right time. If they were aware of such information in advance, they can avoid using such water and can search some other alternative sources of water. Thus, residents can protect themselves from harmful effects of water due to poor quality of water. Smart city residents were provided with access to different recreational activities such as swimming, canoeing, recreational fishing in water for relaxing. The following statements were acknowledged by the residents of the smart city when I inquired about the interested recreational activities in water.

"*For relaxing especially during weekend, I like to go for swimming to keep myself fit and healthy. I also enjoy fishing with my friends*" R1

"*My favorites are canoeing and swimming. I prefer to go for it during summer."* R2

Different interviewees have shown different interest in recreational activities. It helped to map out he different recreational activities related to water with the water quality data collected by the digital water quality monitoring system for the smart city.

5.2 Design of Service Blueprint Illustrating Digital Water Quality Monitoring Services for Smart City Residents

The insights gained by the interviews with smart city residents motivated me to create a research based current-state user journey map of a smart city resident as shown in the figure 3. In developed the journey map, the user is a smart city resident who planned to go for swimming along with his kids to the lake near by the city where he lives. The journey of the smart city resident for swimming is just an example, the developed user journey map can be applied to other activities such as drinking and fishing. It is divided into six phases which was explained below.

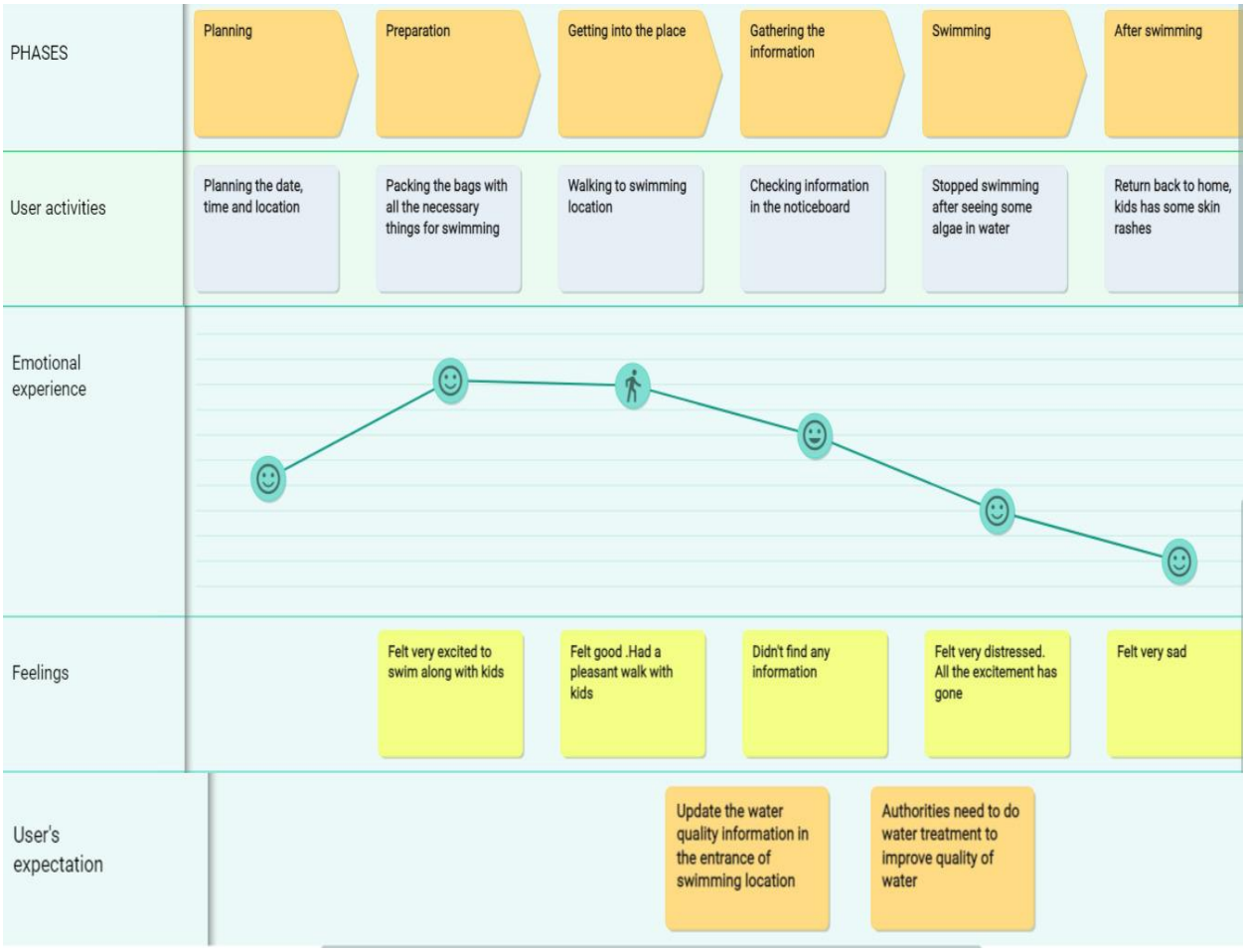

Figure 3. Research based on current-state user journey map of smart city resident for swimming.

- Planning: In this phase, the smart city resident selects the appropriate time, data and location for swimming. He is very happy and hoping that he would have great enjoyment there in water.
- Preparation: He packs his bag with all the necessary things including his kid's necessaries for swimming and leaves home. He as well as his kids seems to be so excited while leaving home.
- Getting into the place: Since the selected river is nearby his home, he opted to walk with his kids. Even though it is hot summer, they had a pleasant walk. The kids were so happy when they saw the river.
- Gathering information: After reaching the river, the smart city resident did not find any people to enquire about the quality of water for swimming. He walked to the entrance of allotted places for swimming to see the notice board to know whether there are any restrictions for getting into water. But he didn't find any such information and thus decided to go ahead with the plan.
- Swimming: The user along with kids went to the river and started swimming. They were very happy and suddenly the smart city resident noticed some green coloured algae in water. He felt very distressed and asked the kids to get out of the water. Then they returned back to home unhappily.

- After swimming: On next day, one of kids had mild skin rashes with itching. It was a sad experience for the smart city resident.

The developed user journey helped to identify the moments of truth of smart city resident, where he experienced some pains while engaging in swimming. The main pains experienced by the smart city residents were the presence of some algae in water while swimming and also when his kid got skin rashes after swimming. This was stated by the smart city residents during the interview.

"*When I saw skin rashes on my kid's body on the after the swimming, I felt very sad."* R2

"Of course, it was when I found that algae in the swimming pool." R3

These identified pains tainted the entire swimming experience of the resident as well as the kids. This pain will be common problem that could hit all the smart city residents while swimming unless the water in river is treated properly. Also, this problem can be resolved by providing real time water quality information to the smart city residents in advance. Thus, by designing a digital water quality monitoring service for providing such real time water quality information will help the smart city residents to take a decision at right time. This could be identified as an opportunity for gain in the smart city resident's swimming experience.
Thus, the research based current state of user journey map identified water quality related problems faced by smart city residents in accessing water related activities in smart city is the listed below

- Health issues due to poor quality of water.
- Lack of access to real time water quality information.
- Not able to make appropriate decisions at right time.

These identified problems of smart city resident were considered in the design of digital water quality monitoring service for smart city resident. The available real time water quality data collected by the sensors in the digital water quality monitoring system could be used to provide an input for informing the smart city residents about different activities such as drinking, swimming, fishing, agriculture, domestic uses and water reuse for the smart city . This was illustrated the following statements of the resource provider:

"Ph, turbidity, dissolved oxygen, dissolved solids, conductivity and temperature." E1

"Each of these parameters value determines quality of water." E2

"If we are drinking bad quality of water such as water with Ph less than 5, the water is acidic, and it cause health issues." E1

The quality of water is determined by various parameters such as Ph, dissolved oxygen, dissolved solid, turbidity, conductivity and temperature in water which was told by the catfish team. If the water bodies contain some chemical or microbial contaminants, then each of these parameter's values exceeds than its normal value, not fit for drinking because it will cause health problems.

"*The collected details regarding water quality can be used to provide some kind of service. Parameters like pH, dissolved oxygen can decide if water has good quality to use drinking".* E1

"With the pH value, we can decide if water is good for swimming. If it is high, it will cause health problems. Also, we can go for fishing depending on the values of other parameters such as dissolved oxygen, nitrogen, phosphorous". E2

"We cannot say one parameter will affect the complete quality of water. So, according to each purpose we can apply some treatment to improve quality of water and you can use it for other purposes such as in agriculture. But for each purpose, the parameter matters." E1a

Thus, water quality data is an important contributor to many different activities such as fishing, swimming, water treatment, other than the primary purpose of identifying and analyzing potential pollution source in the waterbodies for providing clean drinking water. The value of pH in the water is one of the most important factors of water quality, as it measures whether the water is basic or acidic. If the pH of water is higher, it can cause health issues such as irritation to the eyes, skin and mucous membrane, which make it unfit for swimming and drinking. Also, the value of dissolved oxygen (DO) is an important parameter that determines whether the quality of water is good enough for species can survive in the water source**.** For each purposes of application of water, the water quality parameter is different. So even if it is not good for one purpose, then it can be used for other purposes.

"Mostly in the hospitals and malls, they are using treated water in toilets, cleaning purposes." E2a

"We have to give to the correct person and then by seeing water quality parameter value, he will tell you for what purpose it can be used and what are the steps for water treatment for using for that purpose." E1a

The above quotes clearly expressed that water quality monitoring have the potential for the efficient use of water resources in a sustainable way. If the quality of water is not suitable for drinking purpose, then it can be used for other purpose such as agriculture, fishing, flushing in toilets, cleaning. But quality of water needs to have some basic standard for each purpose. This is achieved by giving water quality parameter value to a third party, who is experienced in this field will inform about the purposes it can be used and can do the necessary treatment for the same. Such treated water, even if not suitable for drinking, but can be used for other purposes in the smart city and thus enabling reuse of water resources without wasting it.

"*Yeah catfish provide real time data. This is made possible with the help of cloud technology which collects data by the sensors and made available in real time to authorized people."* S1

"In catfish 2.0 there is no provision for predicting the water quality for future. But it can be done in catfish 3.0 using some machine learning algorithm as we do for processing and analyzing collected water quality data." A1

The distributed network of intelligent sensor nodes act as a data source where data is collected and delivered in real-time using the cloud technology to the service providers, users, and other stakeholders. The real time information is important for providing efficient services. Access to such information provides an opportunity to provide different useful service by expanding its ability in predicting and decision-making using machine learning algorithms. There are plenty of opportunities for new services using the collected data with a huge amount of wireless sensors distributed in houses, vehicles, streets, buildings and many other public environments of smart city. This was also proclaimed by the service designer while interviewing.

"In smart city, vast amount of data is being available from various sources. So, I think the most important thing is to exploit the data and information to create intelligent solutions that can provide better services for the smart city via smart phone." D2

"Access to data collected by sensors in the smart city will help service designers to design a platform for delivering many online services." D1

There are different smart systems used in smart city which collects data using the sensors attached to it, for deploying many services. These services are being delivered by a software application running online and making its facilities accessible to the residents over the internet via an interface. If the collected data is made accessible to other customers, it can be used efficiently for providing various innovative services for smart city.

"*an interpretation of water quality parameter values in a simple language will be more convenient for people like me." R2a*

"The information displayed to the user must be interpreted in such a way that it is understandable to both experienced and in-experienced people." D1

"Identifying user profile will help the user to navigate to the correct and exact information." D2

Since the digital services will be used by different user profiles and each user will have different purpose. So, if the service is displaying the information in same way, it will be difficult for all the users to achieve their purpose. It will be difficult for the smart city resident to understand and interpret the information regarding water quality. It also takes more time for the user to navigate to the right page according to his needs. Also, water quality service may be used by environmental experts for water treatment, but a resident may be using the same for decision making for personal use. Thus, it will always be good to represent the data in an understandable and simpler way to the smart city resident. But same information can be represented with scientific water quality parameter values, which are more familiar to environmental experts. So, the design of digital real time water quality monitoring services should identify the type of user for the easier navigation to the page containing relevant information to achieve the user's needs.

"The development of a service along with customer enables opportunity for value co-creation and increases the chance for improved service design." D1

Customer participation in the service design can create more value to the services and can ensure their own satisfaction. So, it is important to include the communication process between the customers and service providers in the design of a service to identify future customer needs and ideas. This is done by incorporating feedback or review option in the design of the service. Such feedback option will convey information about customer needs, preferences, suggestions, ideas which will help service providers to enhance service for greater customer satisfaction.

"In order to visualize new service opportunities using existing data, I will start with the empathy map followed by the service blueprint. It is good to incorporate both front-end and back-end processes in the design which helps in easy prototyping." D1

Inspired by the service designer's above quote, a service blueprint is designed from the user journey map by adding layers showing the relationship and dependencies of the frontstage and back stage of the service as well as the support process needed to provide the service. This designed service blueprint illustrates how digital real time water quality monitoring service provides information about different water related activities such as safe drinking water, fishing, agriculture,domestic uses and water reuse to smart city resident and also how the service provider facilitates the need of the resident.

5.3 Results and Findings

The findings from the empirical data and literature overview were presented as service blueprint which was considered as an illustration of design of digital water quality monitoring services for smart city. The

blueprint was prepared from smart city resident's perspective. It illustrates how information about different water related activties can be known by the smart city residents in real time and how such services are delivered by service providers. It also explains how smart city authorities can efficiently reuse water resources, if the water quality is poor. As shown in figure 4, the developed service blueprint consists of five stages: physical evidence, customer actions, onstage, backstage and support processes. Physical evidence is the place where interaction actually happens when smart city resident uses the digital water quality monitoring service. In the study context, physical evidences are mobile application, login page, dashboard and feedback form. Customer actions are the steps, choices and activities, a smart city resident may go through to find water quality for desired purpose. The customer action and onstage activities are separated by 'line of interaction', which indicates the direct interactions between the smart city resident and the digital water quality monitoring service. Onstage activities are activities which are viewed by the smart city resident, whereas backstage activities happen out of sight by them. The two sections were divided by a 'line of visibility' that separates what's visible and invisible to the smart city resident. Support process are a sequence of steps that support employees in delivering digital water quality monitoring services to the smart city residents. The support process and backstage process are separated by line of internal interaction.

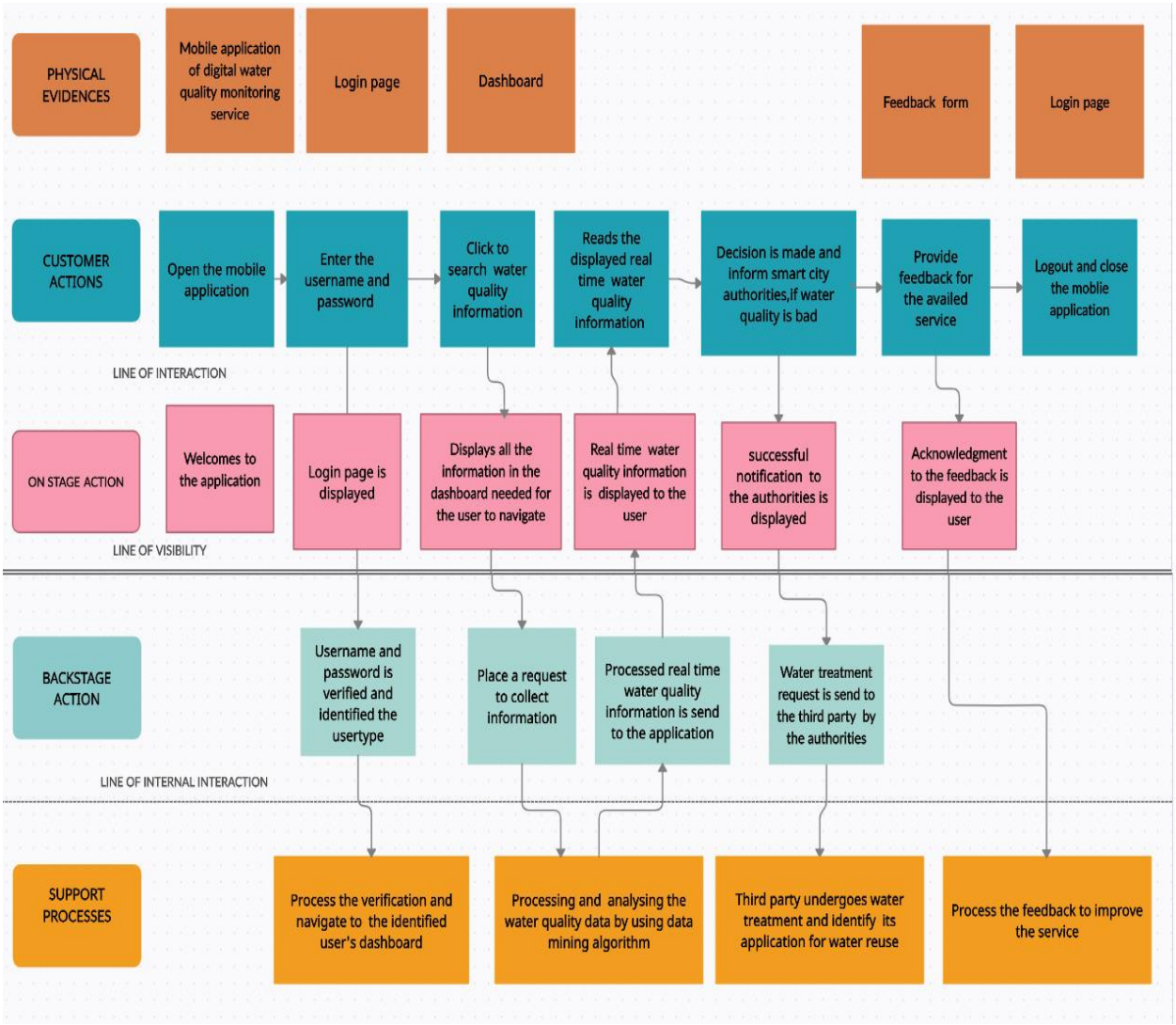

Figure 4. Illustration of digital water quality monitoring service for smart city.

The customer action starts when smart city resident opens the mobile application of digital water quality monitoring service. As an onstage action, customer views a welcome message in his/her mobile phone followed by the option to navigate to the login page. Once the resident reaches the login page, he/she will enter the username and password for authentication purpose to login into application. At that moment, the login page of the application will be displayed in the mobile. Then the verification and identification of the smart city users will be identified and verified on the backstage with the help of some support process. In this designed digital service, there are three users: smart city resident, smart city authorities and third party who were intended for water treatment process. Each of these users will have different capability to understand the interpretation of water quality data displayed by the digital water quality monitoring service .So identification process in the design will help to identify the type of user that have login into the application and also to navigate to the appropriate dashboard depending on the user. Since the digital water quality monitoring service is designed only for a particular smart city, so there should not be any unauthorized interventions to use this service by unauthorized users. To protect from unauthorized access, verification process of the user is designed in the service.

Once the smart city resident enters the dashboard, all the necessary information related to water quality and the options for navigation will be displayed in mobile phone as an onstage action. The smart city resident clicks the option to search water quality for a particular purpose and the request will be send to the server on the backstage. The collected water quality data from the sensors of water quality monitoring will be retrieved from the cloud storage, which is then processed and analyzed using data mining algorithm. This support process will provide real time water quality data and its interpretation, enabling smart city resident to gather information for different activities such as drinking.fishing,agriculture,domestic uses. Also, if the displayed real time water quality is bad, a smart resident has the option to inform it to the smarty city authorities. On backstage, as soon as the smart city resident receives this notification regarding bad quality of water, authorities will place a request to the third party for performing the necessary water treatment process. Then the third party as per the request undergoes water treatment process and identify the application of treated water depending on water quality parameter's value. Even if the treated water is not fit for a particular purpose such as drinking, but it can be used for other non-potable purposes like street cleaning, flushing toilets, swimming. Thus, the illustration of digital water quality monitoring service also enable reuse of bad quality water without wasting it, thereby improving and creating a new source of water resources in the smart cities to meet the needs of present without compromising the ability of future generations to meet their needs.

The illustation of design of digital water quality monitoring service also includes the option for receiving feedback from the users. The smart city resident after gathering information regarding different water related activities, will be navigated to the feedback form page (physical evidence) of mobile application. He/she can give feedback regarding the good and bad experience of the digital water quality monitoring services availed during the time. The support process will receive and process the feedback which are used for the improvement of the service to the smart city. In the meantime, acknowledging feedback is displayed in the mobile as an onstage action. Once all the needs of the smart city resident were done, then he/she will logout and close the application. Thus, the illustration of design of digital water quality monitoring services in the form service blueprint gives a good visual representation of the service process, that can be used for the development of the service. But still it is not the perfect design, iterations of the design through evaluation will help to make more improvements to the design of digital water quality monitoring services for smart city.

5.4 Evaluate

In this stage, three public citizens validated the designed service blueprints that illustrates digital water quality monitoring services for smart cities. The evaluation method used for the study was the proof of concept using validation criteria - whether the developed service blueprint is feasible for development in real world setting (smart city) and is flexible enough to add more services or improvements to satisfy the

customer's individual need. While evaluating the developed service blueprint, two citizens showed their concern about the data privacy.

"Cyber security of the personal details provided by the user must be taken care of. He/she must be guaranteed that the personal data will not be shared with third party."

"since user details are collected for authentication, it will be good to consider how privacy can be addressed"

Since the illustrated service blueprint of digital water quality monitoring service collects details such as address of smart city resident for authentication purpose, the service provider must ensure that it should not be shared with any unauthorized users such as third-party providers without resident's consent. So, by incorporating privacy and data protection mechanism such informed consent, privacy by design principles in the design will create more trust and confidence in using the digital water quality monitoring service. Also, the evaluation gave an insight regarding the missing element in workflow of smart city resident in developed service blueprint, when the resident find the quality of water is good. This need to be resolved in the design by giving proper flow to each service process to avoid unneccessary guessing.

"A graphical representation of water quality results of a particular location selected by user must be made available for a selected period of time. "

One public citizen shared a suggestion regarding the display of water quality data in mobile application. According to his perspective, graphical representation of water quality data of water resources in smart city must be made available to the smart city resident. Also, the evaluation gave the insight of adding an option to view the water quality data and its interpretation in week wise, month wise and year wise. This may help smart city resident as well as the authorities to compare the water quality data over a period of time, that can cause impact on their behavior towards the water usage and thereby contributing to sustainable development of smart city water resources.

The results of evualation of illustated service blueprint of digital water quality monitoring services were 1.Incorporate by privacy by design principles into the design of service blueprint.2.Avoid missing elements in the workflow of smart city resident.3. Include a touchpoint to service blueprint to enable the display the water quality information for a selected period of time.

Thus this study revealed that real time water quality data collected by the sensors of the water quality monitoring system can be replicated and contionously used efficiently for providing digital services to smart city residents.

6. Discussion

In the study, I set out to explore how digital water quality monitoring services can be designed for the benefit of smart cities. Through a design study, I illustrated the design of digital water quality monitoring services for providing information about different activities such as safe drinking water, fishing, agriculture, domestic uses and water reuse to the smart city residents in the form of service blueprint. The usage of bad quality of water causes serious health problems such as skin irritation for smart city residents (Keeler et al., 2012). So, it is important for a resident to know the quality of water before using it. In design of digital water quality monitoring service, water quality data collected by the water quality monitoring system was used to provide information to smart city residents about different water related activities. The design also guides the smart city authorities to facilitate for water treatment, if water quality is poor. The retreated water can be resused again for different activities depending on the quality of water. As highlighted in introduction, this type of services is highly relevant in smart cities, as it manages its water resources efficiently, leading to sustainable development of smart cities (Mounce,2020).

The aim of study was fulfilled by illustrating the potenial of digital water quality monitoring services for smart cities using a service blueprint. I selected service blueprint as a design tool for presenting the findings of the study to visualize all actions which are needed for the digital water quality monitoring services to function and those which are visible to the customer as well as those which arenot (Shostack 1982, 1984). Also, this visualization established a popular place of discussion for service development as well as for the improvement of the designed service (Bitner et al., 2008). The service experience of the illustrated service blueprint was structured in layers and in a partially ordered sequence that articulated insights, defining areas of investigation and analyzed service processes. But Mårtensson et al. (2021) stated that it can limit the degree of service innovation that can be achieved from blueprint of digital water quality monitoring services.

Data access and effective use of water quality data were key elements of illustrated service blueprint, which were properly structured and vetted with data policies enabled effective data-centric decision making (Stillman et al., 2020). The water quality data collected by the sensors in the digital water quality monitoring system in smart city enables continuous real time water quality monitoring in smart city, which can be used for informing smart city residents about different activities such as drinking, agriculture, fishing and domestic uses. During the interviews in the study, it was found that the water quality data can also be used by the smart city authorities for performing water treatment process by third party, if the water quality is bad. Thus, the digital water quality monitoring services in smart cities have the potential not only to inform the real-time health status of water resources to smart city residents but also allows reuse of bad quality water for different purposes after doing the necessary water treatment to it. These two findings of the study were tailored towards the design of service blueprint as an illustration of digital water quality monitoring services for smart cities.

The illustrated service blueprint included verification and identification of user profiles for providing authentication and authorization for digital water quality monitoring services (Todorov, 2007). The verification process helped to limit the seamless provision of the digital water quality monitoring services to the authorized users such as smart city residents, smart city authorities and third party who undergoes water treatment. Whereas identifying process helped the digital service to find out who the user was and then accordingly enabled to navigate to an understandable, correct and relevant information regarding water quality. The displaying of water quality data and its interpretation using visualization techniques depending on the user, helped for conveying potential hypotheses and explored correlations in a simpler way (Mounce,2020). This feature made the design of digital water quality monitoring services user friendly. Also, the service blueprint contained the customer feedback option, that encouraged customers to provide useful feedback regarding the limitations of the current version of services (Ye and Kankanhalli, 2020) for improving the digital water quality monitoring services for smart cities.

Even though the verification, identification and customer feedback process have many advantages, the evaluation of service blueprint revealed that it may create privacy issues for the smart city residents. Since this service uses smart city resident's data such location, information for personalization of service cause serious information security and data privacy issues to the smart city residents. Cavoukian et al., (2010) proposed privacy by design principles, which can be applied in the design of digital water quality monitoring services for smart cities in future.

Almost 66% of the world's population are projected to live in urban areas by 2050 [1]. This may create very substantial and highly complex human, societal, scientific and environmental issues, including how people live, travel around cities and receive services. In addition, number of smart cities are increasing day by day, but their requirements are not met due to increased depletion of water resources. So, the digital technologies providing digital services needs to provide information about water quality and facilitate community developments and social cohesion within increasingly intensive urban environments. Even if the sustainability agenda is global and has been primarily addressed within the EU at both the community and national levels, local and regional governments have also become active advocates of sustainable development. So in smart cities within the context water, digital technologies for providing services for improving water resources and wastewater treatment, monitoring and controlling water and providing real-time information is needed to help water companies and residents to manage their water resources in a

better and sustainable way (Mounce,2020). The illustrated service blueprint of the study explained how smart city resident can use this service for getting water quality information for different water related activities. Also it explained how smart city authorities can trigger the water treatment process using water quality data to manage the smart city's water resources, thereby enabling sustainable development of smart cities as per the words of Chen and Han (2018). The reuse of bad quality water using this service will surely increases the availability of water in smart cities, thereby contributing to UN sustainability goal 6: Ensure availability and sustainable management of water and goal 11: making cities sustainable. The study also ensured that theillustation of design of digital water quality monitoring service will be used in socially responsible ways, will meet social needs, and will avoid harmful effects to health and welfare in smart city (Myers and Venable, 2014).

6.1 Study Implication

The results of this study are relevant for designers and researchers in designing and developing digital water quality monitoring services in smart cities. Our study provides a holistic view of how to design digital water quality monitoring services for the sustainable development of smart city by illustrating service blueprint. Even though service blueprint is prepared from the smart city resident's perspective, but it can be used as foundation for preparing service blueprint for other actors such as smart city authorities, third party for water treatment in the involved in the service. Also, the illustration of service blueprint of digital water quality monitoring service can be used as an assessment tool for stakeholders before the implementation, where improvements and customization can be done to existing design. Though study was conducted in smart city, but the results of finding can also be applied to other communities for the sustainable development. Also, the empirical study gave an insight about predicting water quality by applying machine learning algorithms on the collected water quality data, which can be considered in future in designing digital water quality monitoring services.

6.2 Study Limitations

The fundamental limitation of the study was to find out the exact smart city, which has mentioned in the related literature. The access to such smart city comprising with the whole concept of smart mobility, smart grid, smart buildings, smart environment, smart governance was not possible in the study. The smart city residents selected for the interview was from city, which was built on the basis of concept of smart city. So, if they were from the exact smart city, the data collection from them will be more extensive. Next limitation was due to the pandemic of COVID 19, most of data collected was done through online video call. So there occurred lag issues. repeating questions and asking the participants to repeat the answers during interviews. This might have affected the rapport with the interviewee and the quality of collected data. Also, the numbers of people engaged in the evaluation process was limited to three public citizens due to time limitation. If more people were involved, more feedbacks will have contributed to the study.

7. Conclusion and Future Work

The main conclusion that can be drawn from this study is that there are several opportunities that can be explored for smart city using digital water quality monitoring system. The study first investigated the main challenges faced by the smart city residents related to water quality which implied the need of digital services to solve it. Service design methods were employed for exploring and exploiting knowledge of water quality monitoring system for designing digital water quality monitoring service for smart city. The finding from the empirical study revealed that water quality data can be used to provide digital services to inform smart city residents for different activities such as safe drinking water, swimming, agriculture, drinking, domestic uses and water reuse. Ideally, these findings are replicated in a study to design the digital water quality monitoring service for smart city by illustrating service blueprint.

The illustrated service blueprint explains how digital water quality monitoring service can inform smart city residents about the and how the water treatment process can be facilitated by the authorities for sustainable development of smart city. Implementing such services helps to monitor water quality, thereby which it can reduce consequences such as health issues caused by using bad quality water. Further research has possibility in finding how the developed service blueprint can be extended to a prototype by incorporating features and insights collected from this study.

The next step in developing this design further would be to address privacy issues of digital water monitoring service, while illustrating service blueprint. The aspects of privacy by design principles need to be considered in the design of digital water quality monitoring service for smart city, since the user profile identification and customer feedback was included in the designed service blueprint. Thus, by integrating privacy as a default setting in the design of a digital service may increase value creation. Also, further study can be conducted on how machine learning algorithms can be used to predict water quality. So, combining such machine learning algorithms with the developed service blueprint in future take digitalized water quality monitoring services for smart city to new heights.

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