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LoRaWAN AS PART OF A SMART CITY STRATEGY

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ABSTRACT

The LoRaWAN technology is repeatedly mentioned in connection with smart city initiatives, as it moves in the field of connectivity and IoT environment. This paper examines the role of LoRaWAN in smart city strategy and what vulnerabilities are known in the project using LoRaWAN. With help of a concrete use case of the city of Pforzheim (Germany), a SWOT model is set up and tested with experts. From this it can be deduced that the LoRaWAN technology is currently undergoing an interesting development but also has to overcome any hurdles in the urban environment.

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1. Introduction

The main aim of a smart city is to make use of technology to provide its residents with services that can help solve problems occurring in urbanization. Following a smartphone, a smart home will now become a norm in everyday individuals' lives and the majority of the cities are thus becoming "smart" possessing an intelligent environment (Lopes and Oliveira 2017). A smart city is a term used for a city that works with information and communication technology (ICT) to improve the efficiency of operations, share useful information with the public, and bring development in the area of public welfare and health, and governmental services. Transportation and social services are improved in a smart city. The objectives also include waste minimization and sustainability (Lopes and Oliveira 2017). The goal of a smart city is to increase performance, maximize resources, decrease waste, consumption, and prices, and, most significantly, improve the citizens' quality of life. Many of the issues that Smart Cities confront can be solved with LoRaWAN, which is especially well suited for beneficial applications within a smart city (Lacinák and Ristvej 2017).

The initial LoRaWAN specification was released in 2015, and since then, this technology has seen significant implementation and adoption by cellular network operators all around the world (Eldefrawy et al. 2019). LoRaWAN is a Low Power Wide Area Network (LPWAN) protocol that improves cable terminals or battery-powered mobile devices. LoRaWAN is one of the most important IoT (internet of things) technologies in the world, and it is maintained by an open membership, non-profit LoRa alliance (Eldefrawy et al. 2019). LoRaWAN was created exclusively for IoT applications and has evolved as the foundation for IoT applications in smart cities. By the year 2050, the United Nations predicts that 68 percent of the world's population will be living in smart cities (Marzouk and Othman 2020). Many cities around the world have achieved a similar aim using LPWAN, which is a lower-powered radio technology called LoRaWAN. The open-source community built a version of this technology called "The Things Network" (TTN) in 2018 (Woodhead 2018). Several aspects of LoRa technology have piqued academics' interest.

Numerous scientific publications encourage further research into IoT security in general as well as in certain areas such as smart farming/agriculture. Regrettably, developers and researchers are now having a tough time finding security recommendations that are simple and clear to help in the development of IoT solutions, and even more challenging when it comes to it particularly discussing agriculture. Another problem that arises is the wide range of IoT technologies and protocols already being used and implemented. We have kept our focus on LoRaWAN in this study as it is gaining the most recognition in the industry, science, and agriculture. Although Lorawan is only a few years old, there is a lot of work that covers security concerns. We see a need for a comprehensive review of security risks as well as mitigation solutions as new vulnerabilities are introduced and new LoRaWAN definitions emerge.

2. Literature Review

2.1 Smart City

Cities use technologies, including information communication technology (ICT), to enable a more efficient provision of services (Albino, Berardi, and Dangelico 2015). Especially during the time of the COVID-19 pandemic, the tremendous need for improved data and information on the population, which is mainly economically present in urban areas, became evident. The publications, therefore, show an increasing interest in transforming the physical environment and performance of a city to a more digitalized level (Wirsbinna and Grega 2021).

2.2 Smart City Definition

In the literature, however, there is still no uniform Smart City definition. Depending on the definition, the Smart City concept generally encompasses the meaning of the word ‘intelligent’: Smart City, ubiquitous city, knowledge city, digital city, sustainable city, etc. There are many definitions of a Smart City, but none can claim to be enforceable (Dameri and Rosenthal-Sabroux 2014). Especially in recent years, several scientific papers have been published on the subject, with many of them not being older than 10 years (Albino, Berardi, and Dangelico 2015). Ruhlandt (2018) conducted a systematic study according to the Webster and Watson 2002 (Webster and Watson 2002) review standard to cluster the different definitions and studies. However, the concept of a Smart City is still not clear. Different approaches are used, but their differences are also not very clearly defined (Townsend, 2017).

Some Smart City definitions mentioned in the literature are outlined below:

‘A Smart City […] capitalizes on the opportunities presented by Information and Communication Technology (ICT) in promoting its prosperity and influence’ (Odendaal 2003).

‘A Smart city is a city well performing in a forward-looking way in these six characteristics [economy, people, governance, mobility, environment, and living], built on the “smart” combination of endowments and activities of self-decisive, independent, and aware citizens’ (Giffinger et al. 2007).

‘[…], the concept of the Smart City has recently been introduced as a strategic device to encompass modern urban production factors in a common framework and, particularly, to highlight the importance of Information and Communication Technologies (ICT) in the last 20 years for enhancing the competitive profile of a city’ (Caragliu, del Bo, and Nijkamp 2011).

‘The identified clusters are smart governance (related to participation); smart human capital (related to people); smart environment (related to national resources); smart living (related to the quality of life); and smart economy (related to competitiveness)’ (Lombardi et al. 2012).

‘[…] define Smart Cities as places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems’ (Townsend, 2013).

‘Smart Cities is a term […] to describe cities that, on the one hand, are increasingly composed of and monitored by pervasive and ubiquitous computing and, on the other, whose economy and governance are being driven by innovation, creativity, and entrepreneurship, enacted by smart people’ (Kitchin 2014).

The different aspects of the Smart City definition can be summarized as follows:

1) The technology approach of a Smart City strongly links ‘smart’ with applications of ICT. ‘The use of smart computing technologies to make the critical infrastructure components and services of the city - which include city administration, education, healthcare, public safety, real estate, transportation, and utilities - more intelligent, interconnected, and efficient’ (Washburn et al. 2010).

2) The governance-focused approach focuses on the ‘smart’ interaction of many factors, but also on the possibility of differentiating themselves from other groups. Smart City as strategic urban orientation, while networking with governance, is of certain importance. ‘We believe a Smart City to

be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance' (Caragliu, del Bo, and Nijkamp 2011) or 'Academic literature highlights governance-related elements of Smart Cities. It suggests particularly three elements: (1) e-governance, (2) engagement by stakeholders, citizens, and communities, and (3) network-based relationships such as partnerships and collaborations' (Gil-Garcia, Pardo, and Nam 2015).

3) Many of the definitions in the literature try to describe the multidimensionality and complexity of different areas of a city in a community approach. Giffinger (Giffinger et al. 2007) identified the area's economy, people, governance, mobility, environment, and living identifiers, which are combined in a Smart City. Due to the complexity of the Smart City approaches further systematic literature analysis and reviews are available on the various Smart City definitions (Ismagilova et al. 2019; Moustaka, Vakali, and Anthopoulos 2019; Ruhlandt 2018; Zheng et al. 2020).

Table 1 shows infrastructure types in the Smart City along with the definitions.

Table 1. Infrastructure Types in Smart City and Definitions

Infrastructure Types	Description	Sources
Institutional	Institutional infrastructure encompassed Smart City governance, which included creating political strategies, governance accountability, and public participation in decision-making.	(Mohanty, Choppali, and Kougianos 2016)
Physical	The physical infrastructure's major objective is to secure the Smart City's long-term viability in the near and distant future. Natural deposits and power, ICT architecture, structure, and metropolitan design are considered part of the physical infrastructure.	(Silva et al. 2018)
Social	The intellectual and human capital and the quality of life are all covered by social infrastructure. The growth and viability of the Smart City are regarded as dependent on social infrastructure and social awareness.	(Ismagilova et al. 2019)
Economic	The Smart City's economic infrastructure includes everything from e-commerce and e-business to different performance metrics for analysing public spending, employment rates, energy consumption, Smart City project financing, and count of individual GDP.	(Haughton, Counsell, and Vigar 2008; Mohanty, Choppali, and Kougianos 2016)

Source: Wirsbinna & Grega (2021)

In many definitions of Smart City (Technology Approach) in the past, the focus is on the role of communication infrastructure. However, this aim reflects the period between 1990 and 2000, when the Smart City label initially gained attention as ICT reached a wider European audience (Caragliu et al., 2011) and as the development of the internet and digital reality plays a major role in urban development.

2.3 LoRaWAN Networking

LoRaWAN provides secure two-way communication in both directions thanks to the star network topology. Despite the many benefits of LoRa / LoRaWAN technology in building a smart city, including simplicity, power consumption, low bit rate, wide coverage, private network deployment, security, and ease of use thanks to its star-star configuration, recent studies have shown that there are several possible problems with LoRa / LoRaWAN networks, especially in terms of scalability in large-scale scenarios. The LoRa Alliance develops and maintains the LoRaWAN, a cloud-based MAC layer networking protocol that uses the physical LoRa layer to define higher levels of long-range, long-range networks. It is an LPWAN (Low Power Wide Area Network) technology that allows you to connect batteries to the Internet on regional, national, or global networks using batteries (de Carvalho Silva et al., 2017, pp. 1-6).

Furthermore, the LoRaWAN protocol is used in smart city projects to route the network layer between LoRaWAN gateways and LoRa devices. The physical LoRa layer provides long-range communication links, while the LoRaWAN protocol is used to control the network layer between LoRaWAN gateways and LoRa devices. LoRaWAN also controls the data rate, communication frequency, and transmission power of all request-driven asynchronous nodes in the network (Jonathan de Carvalho Silva; Joel J. P. C. Rodrigues; Antonio M. Alberti; Petar Solic; Andre L. L. Aquino 2017). The terminal devices send data to neighboring gateways that route media to a cloud server (Things Network (TTN)) that is integrated into some IoT platforms. The network server that controls the network and provides data security filters out duplicate packets. Incoming information is sent to the application's servers through one of several integrations.

2.4 Smart LoRaWAN projects in cities

Calgary launched a joint venture in 2016 to develop the LoRaWAN smart city network, which was developed by scientists and students from the University of Calgary, as well as local IoT startups (Song et al. 2017). The project was completed in September 2017, and the network provides exceptional security throughout Greater Calgary, from downtown to distant locations. Calgary has developed its LoRaWAN network at a lower cost thanks to the city's continued good infrastructure expenditures transforming it into a smart city (particularly the fiber network) since 2000.

In addition, the Hamburg-based ZENNER has focused its efforts on digitalizing the energy and water supply businesses. It also has a joint venture with the energy management company Minol Messtechnik to operate Germany's largest LoRaWAN network in the electricity market. The LoRaWAN network of the Minol-ZENNER Group supports over 800,000 instruments for measurements and sensors and comprises over 6,000 IoT gateways, another huge step towards the development of a smart city. Kerlink LoRaWAN provides networking hardware, networking software, performance and administration software, and value-added applications. It includes over 120,000 systems in 69 countries that "cover all main areas of the Internet of Things" (Basford et al. 2020).

Similarly, the University of Pforzheim in Germany has expanded its LoRaWAN network, which was researched at the University's Technology Center to include smart city applications and Industry 4.0, as well as 5G industrial collaboration with a university in the south of the country (Krutwig et al. 2019). As part of the pilot program, the city council has been trying to irrigate trees in the urban area since 2000. One of Germany’s leading colleges, the University of Pforzheim, has announced that the LoRaWAN network will be expanded by installing LoRaWAN ports to “where this was not possible before”. The University of Pforzheim is bordered by the Black Forest in the southwestern part of the country (Krutwig et al. 2019).

2.5 LoRaWAN Security Issues

The LoRaWAN protocol has been examined by many researchers and several vulnerabilities have been found depending on the version. Aras et al., (2017) focused on the physical layer (LoRa) of the LoRaWAN and found that the LoRa network may be affected by external devices. In another LoRaWAN security statement, Yang et al., (2018) identify five attacks that pose a threat to privacy, presence, or justice, as well as multiple responses. Since then, the introduction of LoRaWAN v1.1 has solved some of the uncertainties (Butun, Pereira, and Gidlund 2018).

Many security-related enhancements were included in this release, as well as the decision to take part in favor of v1.0 backward compatibility. Nevertheless, as Dönmez & Nigussie, (2018) observed when working to restore this type of relationship, only the most important debate remains - all the other money in the statement is lost (pp. 51-58). Their research is the first to identify the names of attacks against supported versions of LoRaWAN. Butun et al. (2018) only developed a comparative name for LoRaWAN v1.1, however, it does not contain many of the objections and security recommendations that we hope will appear in this form (p. 3). We have not reviewed a LoRaWAN Security Spy screen that has decided on security protection for the key, especially since the release of LoRaWAN v1.0.4.

3. Materials and Methods

LoRaWAN has been a well-known rising technology for several years now and hence, there are already enough surveys conducted that can help inspect the security of the protocol. As a result, this article will review the findings of a case study of a LoRaWAN project. SWOT analysis was used for this research.

3.1 Description of the Case Study (City of Pforzheim)

In the tough positioning battle of the conurbations in Baden Würtemberg Stuttgart, Karlsruhe, and Pforzheim, Pforzheim with about 120,000 inhabitants in the Northern Black Forest region has developed a smart city strategy from 2019 to 2020 (Kevin Lindauer, 2022). Pforzheim wants to shape the digital transformation and use digitization for the benefit of urban society.

The following goals are in the foreground in the development of the Smart City Pforzheim (Kevin Lindauer, 2022):

1. Increasing the friendliness of the citizen through the provision of time- and location-independent communication channels and administrative services
2. Resources and increased efficiency through process optimization and automation
3. Increase in workplace and employer attractiveness
4. Promoting digital skills and competences
5. Expansion of digital participation opportunities
6. Provision of data protection

3.2 Development of an IoT infrastructure

To achieve these goals, various fields of action were defined. In the field of action of infrastructure, powerful and comprehensive communication infrastructure is to be built, which is seen as the basis of digitization. The construction and expansion of infrastructure for the Internet of Things (IoT) are intended to offer the transmission of sensor data and thus numerous application possibilities for urban society.

To build up the radio network nationwide for the geographical typology of Pforzheim, radio network planning was carried out. IoT radio network planning is aimed at preparing the network expansion as optimally as possible. The result of this radio network planning (see Figure 1) has shown that Pforzheim requires 8-10 gateways. Public buildings, as well as buildings with municipal participation, were used for distribution and installation.

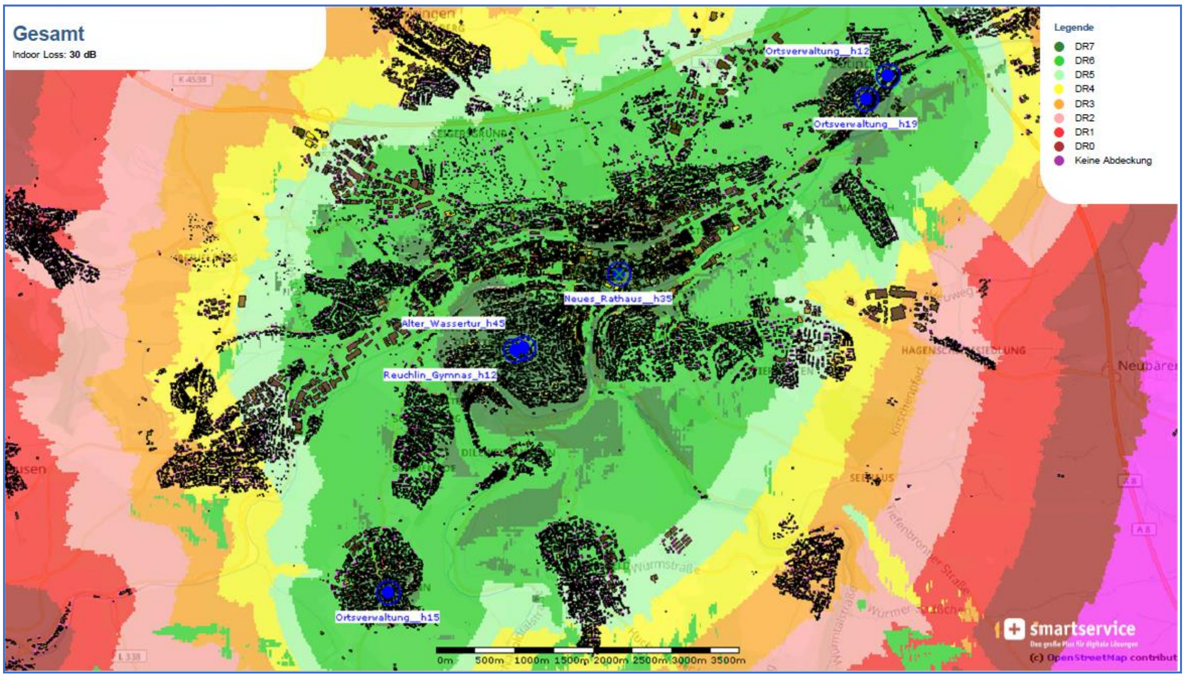

Fig. 1. Project documents for the entire radio network planning LoRAWAN Pforzheim
Source: Own Source

3.3 Smart City Use Cases of the LoRaWAN Network

The LoRaWAN network should be used for several use cases.

Table 2. Case Study in Pforzheim

Case study	Description
Parking Sensors	In this case, parking sensors for reserved parking spaces (fire brigade, ambulance, disabled places) were installed in the first step. In addition, the parking areas with public charging infrastructure. The aim is to measure the parking status for the city society but also sovereign security.
Soil moisture sensors	In this case, the increasing dryness and heat period in summer is to be counteracted by determining the amount of water required for the public green spaces with the help of soil moisture sensors. The aim is to use water resources even more efficiently to provide parks and green areas with sufficient water.
Queue Sensors	The waste management area of the city of Pforzheim operates public waste stations. Citizens can dispose of larger garbage sorted there. These can be household waste, bulky waste, recyclables, green waste, organic waste, etc. The citizens of the city use the collection point very irregularly. It has been shown that there can still be long car queues. As a result, the adjacent residential infrastructure is severely affected. The queue is intended to clarify the waiting times to the citizen and thus also equalize them independently.
Connection visualization district heating leakage	The local energy supplier has an extensive district heating network. The water losses within this infrastructure should be found more efficiently. Appropriate sensors can better limit water leaks in the different sections of the network. The search and workload are thus significantly reduced.

Source: Own Source

However, the results will also apply to LoRaWAN operations and other departments. The following are research questions of the relevant study (RQs):

RQ1: What vulnerabilities are known in the project using LoRaWAN?

RQ2: What role does technology play in smart city initiatives?

To properly approach these research questions and provide answers, a case study of IoT applications will be analysed first to give an idea of how IoT applications work. To answer the RQ1 the SWOT Model will be used.

3.4 Validation of SWOT Model

Subsequently, a systems thinking approach was applied to establish the interrelationships between the SWOT factors using a causal loop diagram (CLD). An emerging CLD representation of the interrelationships between these factors is shown in Figure 2 and shared with five experts for validation.

In validating the SWOT causal loop diagram (Figure 2), interview questions as described below were sent to five different experts. The interview questions cover the content, utility, structure, and acceptability of the SWOT loop diagram. The interview questions were:

(1) Do you think any variables are missing from the list?

(2) Can you briefly describe any variables that should be correlated?

(3) Do you think the structure of the causal loop diagram represents the SWOT of smart city implementation?

(4) Do you think the diagram is simple enough?

(5) Is there any ambiguity in the CLD?

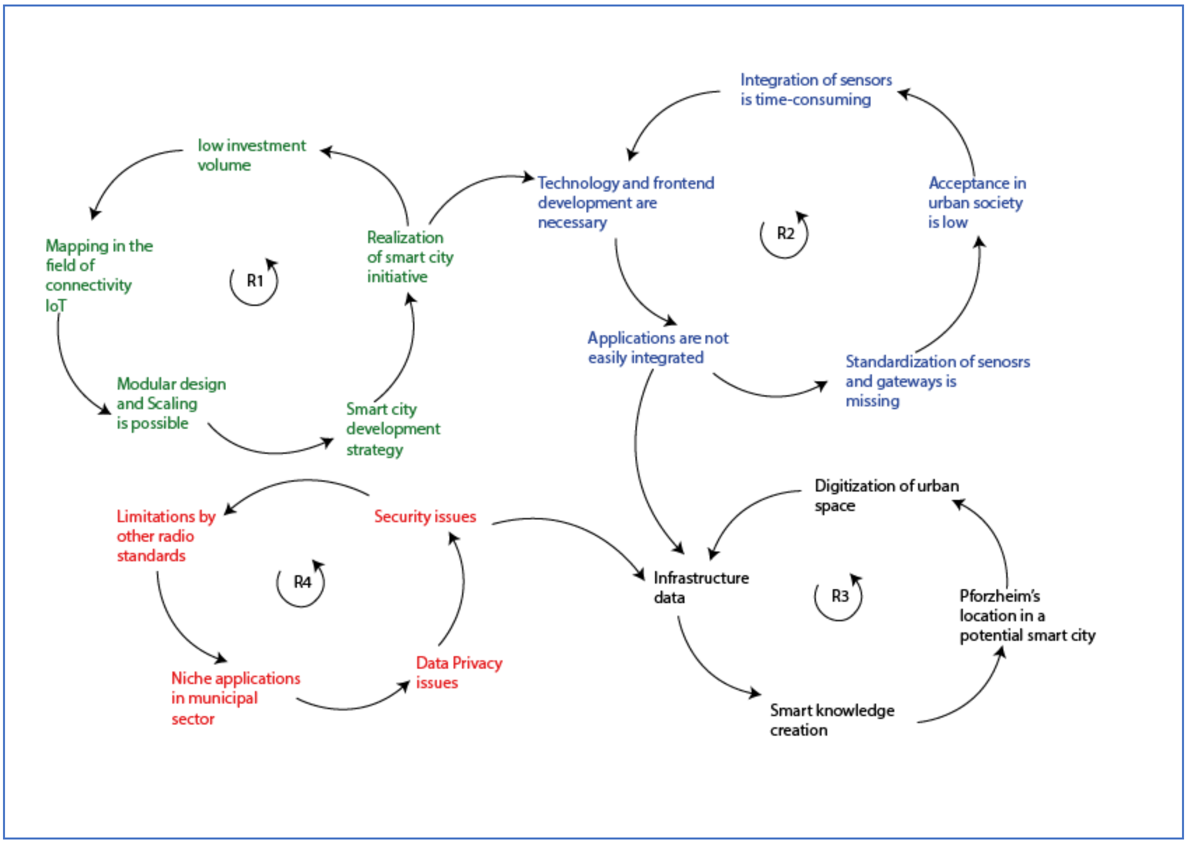

Fig. 2. SWOT Analysis causal loop diagram (Green—Strengths; Blue—Weaknesses; Black—Opportunities; Red—Threats)
Source: Own source

The experts contacted for the purpose of validation of the SWOT causal loop diagram were mainly academics from different areas of Germany and Bulgaria on the LoRaWAN Expo in Paris 2022 via the Social Media Platform LinkedIn. The feedback given by these experts provided a multi-dimensional overview of LoRaWAN technology. The experts' demographics are provided in Table 3.

Table 3 Features of experts involved in the validation phase

Experts	Location	Profession	Years of experience
EXP-1	Bad Wildbad (Germany)	Management consultant	20
EXP-2	Eisenbach (Germany)	Information technology clerk/telecommunications electronics technician	15
EXP-3	Bernau bei Berlin (Germany)	Dipl. industrial engineer	25
EXP-4	SOFIA (Bulgaria)	CEO	8

Source: Stadtwerke Pforzheim GmbH & Co KG Netigate Survey via LinkedIn

4. Results

4.1 Transitioning towards a Smart City Environment using SWOT Analysis

Table 4 provides a summary of the comparison of strengths and weaknesses, categorized according to SWOT of Pforzheim Smart City transition as elicited from the findings of the case study at the city.

Table 4. Strengths, weakness analysis of the case study of Pforzheim's Smart City

Strengths	Weaknesses
Low investment volume compared to other wireless standards	Integration of sensors is time-consuming, no plug and play – mechanism
Smart City Use Cases can be mapped in the field of Connectivity IoT	Standardization of sensors and gateways is missing
Modular design is possible and thus scaling over time	Acceptance in urban society is low
	Use cases are characterized by high infrastructure

Source: Own Source

Table 5. Strengths, weakness, opportunities, and threats (SWOT) analysis of the case study of Pforzheim's Smart City

SWOT	Strengths	Weaknesses
Opportunities	Digitization of urban space through increased connectivity and collection of infrastructure data	Applications not yet easily integrated Technology and frontend development are necessary
Threats	New technology, which is currently even cheaper to build, but which can also be limited by other radio standards.	Niche applications in the municipal sector

Source: Own Source

4.2 System Thinking

Systems thinking can elucidate the causality, action, and impact of cybernetic decisions (Abbas et al. 2018; Hassmiller Lich et al. 2017; Khayut, Fabri, and Avikhana 2014; Miki, Kojiri, and Seta 2015). It contains loops leading to causal archetypes derived from the main attributes of the system (Cabrera et al. 2018; Omotayo et al. 2020). Therefore, the system thinking aims at understanding how one factor affects another and why (Omotayo et al., 2020). Application in organizational research and management, CLD (Causal Loop Diagram) reveal additional attributes as they develop (Omotayo et al., 2020).

The SWOT causal loop diagram in Figure 2 applied the SWOT analysis in Tables 3 and 4 to describe an understanding of a city transition into a Smart City. The attributes (green, black, blue, and red) all represent strengths, opportunities, weaknesses, and threats, respectively. Some other variables also emerged during developing the SWOT CLD. These are Smart City development strategy (S); data privacy issues (W); security issues (T); and revenue generation (O). In order to develop an understanding of SWOT CLD for Smart City, the SWOT causal loop diagram in Figure 2 was validated through expert interviews.

The summary of the expert's views is explained in Table 6. These include answers to all the questions from different experts. Suggestions on structure, loop, and implementations were given. Other suggestions including weaknesses were also incorporated in the table.

Table 6. Highlights of the summary of feedback obtained from expert panel based on the questions

Summary of the expert's comments on interview questions
Simple technology, low costs compared to the mobile network, diverse application possibilities with the integration of a wide range of sensors.
Quick entry, sometimes "plug-and-play" capable, relatively easy to understand and therefore to communicate, no large investment, thus lowering the decision barrier, Multi-utility approach: several use cases in the company enrich the acceptance and strengthen the WANT, Sub-metering is a use case, especially for utilities, that can be presented directly in economic terms > this in turn facilitates pilot applications without a quick economic perspective (smart waste, etc.)
Potential in SWOT analysis especially in the area of parking spaces and municipal infrastructure. From emptying rubbish bins to reading meter stands and recording the number of people.
Unlicensed band, affordable connectivity price and easy network deployment if there's not already a network available in the city.
The problem of prioritisation (what has the greatest impact / amortisation of costs) as well as diversity is also the problem of technology. Most municipal utilities get bogged down with solutions instead of focusing on 3-4 use cases.
Another weakness with simultaneous advantage: the small data width. The bandwidth is not sufficient for effective monitoring of hot spots with cameras. Bandwidth not suitable for some applications - e.g., Video monitoring. So, they must be covered with gateways.
Choosing the right partner is important, however, the application possibilities mentioned must also be used for commercial and industrial customers.
I continue to focus on Pforzheim. In the north, we have had very good experiences with networking to other municipal utilities and providers in terms of use cases. I think some variables are over exaggerated. E.g., Integration of smart sensors is not so complicated. There's no need to develop custom front-end as there are many IoT platforms available. Gateways are standardized, there's also a certification for sensors - look at "LoRaWAN Certified".
All the experts added that there isn't any ambiguity in the Causal Loop Diagram and the structure of the CLD exactly represents the SWOT of smart city implementation.

Source: Author's compilation

5. Implications and Discussion

In the above sections, we reviewed some reviews and case study uses specifically for LoRaWAN networks. Subsequently, in this section, we look forward to addressing the research questions by first analysing the impact of the LoRaWAN network. Second, we discuss the loop diagram presented in the research and, finally, provide steps for future work.

LoRaWAN is a very promising technology in the IoT field due to its open standard specifications and vast network architecture. However, it needs many enhancements to further improve its performance. The scalability of LoRaWAN is challenging due to a large number of end nodes (EDs) and the duty cycle constraints imposed in the transmission. Since nodes in a LoRaWAN network are powered by batteries, power consumption is one of the main considerations for evaluating network performance (Al-Samman et al. 2022). It must be noted that several jobs have looked into the power efficiency of the LoRaWAN network (Abdelfadeel et al. 2020; El Rachkidy, Guitton, and Kaneko 2019; Wu, He, and Shi 2020). This indicates an important area of research for LoRaWAN technology.

The number of vulnerabilities and risk rates associated with a given technology lowers its adoption. This is the reason why security is a major concern for communication protocols. Despite the limited device resources, the LoRaWAN specifications do not forget about security issues. The LoRaWAN specification proposes several mechanisms to ensure data security. Research work has been conducted to assess and detect the vulnerabilities in the LoRaWAN network (Van Es, Vranken, and Hommersom 2018; Fan et al. 2022; Kim and Song 2017; Le et al. 2021; Na et al. 2017; Zulian 2016). To stand out from other technologies, LoRaWAN needs to have a higher level of security. Therefore, researchers have to conduct a lot of research in this respect.

Modern cities face the challenge of combining global city-scale competitiveness with sustainable urban development to become smart cities. Smart cities are high-tech intensive advanced cities that use new technologies to connect people, information, and urban elements to create sustainable, greener cities; competitive and innovative business; and improved quality of life. In this way, SWOT Model is used to find the strengths and weaknesses by using a case study.

The loop R1 emerged from the strengths of the SWOT model loop diagram in figure 2. In loop R1, the realization of the Smart City initiative depends on the strategies and revenues generated. If the city is managed in such a way to create a Smart City, coupled with incentives, then the existing knowledge of Pforzheim's city can be used to understand the other requirements for transitioning into a Smart City.

The loop R2 is engaged with the strengths which are linked to the development of Smart City. It will be easy to transition Pforzheim into a Smart City if the ICT infrastructure of Pforzheim is capable enough with the inclusion of members of that city. In this way, data can be collected from all the users and the information collected will then be used to understand the requirements for a Smart City. The already existing infrastructure in Pforzheim can utilize data into the loop R3 for the development of the Smart City strategy.

Loop R3 shows the opportunities that depend on loop R1 (strengths) and R2 (weaknesses). The loop R3 shows the opportunities of Pforzheim where they are having an existing infrastructure that can create and enhance a Smart City. In loop R3, the revenues generated in Pforzheim are the opportunities that can be used to create and implement sustainable Smart City initiatives. These initiatives are responsible for enhancing smart knowledge creation at the lowest level. The creation of knowledge for Smart City can generate further revenues for Pforzheim city through funding, collaboration, and grants.

Loop R4 expresses the major threats to a Smart City transition in figure 2. Major threats include limitations from other radio standards, data privacy and security issues, as well as niche applications in the municipal sector. The lower funding and revenues are because of the COVID-19 epidemic. Negative feedback from applications for grants will be responsible for the hindrance of transitioning Pforzheim into a Smart City.

In the end, we can conclude that several key factors play their role in transitioning into a Smart City. These key factors are critical to the SWOT factors that are identified and they must be prioritized in management and strategic planning for Smart City initiatives and transitions. The discussion above also shows the critical situation of security and data privacy issues. In this context, it is a major threat to the transition of Smart City. Thus, to develop strategic plans for a Smart City, strengths and opportunities must be focused on as positive factors, and weaknesses and threats should be continuously monitored and reduced.

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