UNIVERSITY OF TURKU

ABSTRACT

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Abstract

This study investigates which benefits occur for the different stakeholder groups of a municipality when a municipality enhances its internal and external services using the technologies IoT and AI with geodata. The stakeholder groups are which are public administration, enterprises, and citizens.

The research method for this thesis was the usage of qualitative case study research. The Case study was focused on a single case – The City of Vienna. First, an analysis of strategy papers for Smart City, digitalization, AI, and IoT was done. Secondly, the documentation for the program" Wien gibt Raum", including the internal software" Kappazunder" and the One-Stop-Shop, were studied and described. Lastly, semi-structured interviews were conducted with five participants. The interviewees had diverse backgrounds. All interviewees were involved in the program" Wien gibt Raum" or have a long-term vision on the further data usage of the gathered data.

As prior literature did not provide a suitable benefit framework, an adapted benefit framework was created. This adapted benefit framework is based on multiple benefit evaluation frameworks from prior literature. With the usage of this framework, it was possible to analyze the documentations and interview results. The analysis with the adapted benefit framework made it possible to demonstrate and categorize the benefits in an organized way.

The analysis results show that the public administration's main benefits are efficiency and productivity improvements, better data quality, and data completeness. In the next step, with the usage of the newly generated data, a further efficiency increase, better decision-making, and better forecasts can be expected. The study showed that the citizens and enterprises mainly benefit indirectly from a better-managed city. A better-managed city will lead to time savings, easier accessibility, a better quality of the information provided by municipalities, and increased quality of life.

Key words	IoT, AI, Geodata, Smart City, Municipality, Benefits, Digitalization

HOW CAN MUNICIPALITIES BENEFIT BY USING IOT AND AI WITH GEODATA TO ENHANCE THEIR SERVICES?

The Case of City of Vienna

Master's Thesis
in IMMIT

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1 INTRODUCTION

1.1 Background

"The technology you use impresses no one. The experience you create with it is everything."

– Sean Gerety

The purpose of this thesis is to show how new technologies can help municipalities to enhance their services. This leads to benefits for different groups of stakeholders. Enhancing their services means, on the one hand, to benefit internally by improved services. On the other hand, it means that external stakeholders such as citizens and enterprises benefit. This thesis will show how municipalities can improve their resident's lives with technology. It will also show that governmental employees can work more efficiently with the implementation of new technologies. The technologies on which this thesis is mainly focused are Internet of Things (IoT), Artificial Intelligence (AI), and computerized geographical data (geodata). Even though the thesis is mainly focused on a combination of these technologies, it cannot disregard other technological aspects such as big data or data mining. All these technologies will only be explained briefly as a specific level of knowledge in these technologies is expected, as it is not the goal of this thesis to explain these on a theoretical level. The thesis will mainly focus on how the public administration, residents, and enterprises can benefit from the implementation of those.

The first section introduces municipalities and Smart Cities and the motivation for the research question, and why it is focused on Vienna. Section two provides a theoretical background and will focus on the literature regarding IoT, AI, and geodata. Furthermore, it explains Smart Cities in more detail and shows some applications using these technologies in a Smart City context. Moreover, existing benefit frameworks are explained and adapted for the usage of this thesis. The third section will explain the methodologies which have been used to conduct this study. The fourth section explains Vienna's Smart City Strategy and various IT Strategies. Additionally, it explains a use case of these technologies in Vienna with official documentation. This section will end with reporting the interview results with experts from Vienna. The last two sections discuss the findings, the limitations, and the conclusion of this thesis.

1.2 Motivation

The motivation for this thesis lies in the interest in new trends in information technology. Even though these technologies are not the latest trends in 2021, they are still considered as new technologies, and people without IT education or interest in Information technology most likely do not understand them. Nevertheless, these technologies are getting more and more attention in ordinary newspapers, as they can make people's lives easier. My working career started at the City of Vienna as an apprentice in 2008. I experienced how technology can change and improve efficiency drastically. And I was able to experience first-hand the changes brought about by new and better information technology, particularly a connected workflow within different municipal departments called ELAK (electronic file). ELAK is an E-Government software and is used in the German-speaking area by all different levels of government. These changes taught me that technology implemented to improve public servants' work benefits the government and all citizens, as the services from the government get faster and easier to use. On the one hand, my interest and joy for new and interesting information technology can make lives easier and more comfortable. On the other hand, my extensive experience in the public sector is my motivation for this thesis.

1.3 Municipalities & Smart Cities

There are many different systems of governing a country; there are also different levels of government. This thesis focuses on the local government level, more particularly on a municipality government level. Dictionary Merriam Webster defines a municipality as "a primarily urban political unit having corporate status and usually powers of self-government" (Merriam-Webster, n.d.). In Austria, a municipality is referred to as a city that has a statute. For simplification, the terms city and municipality are used interchangeably throughout the thesis. This is very important as the term Smart City is used quite often in this thesis. There are many different definitions of a Smart City. However, according to the European Union, "a smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business." (European Commission, n.d.).

A Smart City does not only mean the use of information and communication technologies and fewer emissions, but it means, among other things, smart urban transport networks, more efficient ways to light and heat building, and a more interactive and responsive city administration (European Commission, n.d.).

The City of Vienna defines the term Smart City as a future-oriented, progressive, and resource-efficient city, which also provides a very high quality of life. On the one hand, a Smart City promotes social and technological innovations. On the other hand, it links existing infrastructures. A Smart City focuses on new forms of governance and public participation. It takes long-term implementations to help a city achieve the goal to become smart. Smart Cities tackle global challenges such as climate change and scarcity of resources. However, a Smart City should also secure its economic competitiveness and increase the quality of life for the urban population (Stadt Wien, n.d.-b).

1.4 Case organization: City of Vienna

The empirical part and the discussion will be focused on Vienna. Therefore, it is essential to explain and introduce Vienna and its municipality. About 1.92 million inhabitants live in Vienna (Statistik Austria, 2021). It is the capital of Austria, and it is also its own federal state. It can be considered Austria's economic and political center. Vienna is the 5th biggest city in the European Union by population. Nowadays, Vienna is most known for its cultural heritage and as a former imperial capital. Needless to say, that a city needs changes to function for a modern society and fit the needs of society. Consequently, that is where the municipality City of Vienna comes in place. The City Administration of Vienna is the municipal council office and the central district authority of the administrative district of Vienna (Stadt Wien, n.d.-a).

Some of the tasks of the City Administration are (Stadt Wien, n.d.-c).

- Responsible for administrative processes, documentation, and file management
- All tasks which are not explicitly assigned to other bodies
- Direct finance and property management of the municipality

As this thesis is focused on Information Systems, the tasks and the composition or any political or legal matters will not be discussed.

As mentioned before, a growing city needs to meet its inhabitants' needs. These needs evolve, and they could be very different in the past. According to a ranking by Mercer, Vienna the most livable city in the world for the 10^{th} time in a row (Mercer, 2019). Another study that shows a similar result was released by the Economist, and it also ranked Vienna as the most livable city in the world for the 2^{nd} time in a row (The Economist Intelligence Unit, 2019). This success does not come from anywhere; a long-term strategic orientation of contemporary urban development seems very important.

1.5 Research question

The research question for this thesis is "**How can municipalities benefit by using IoT and AI with geodata to enhance their services?**". This thesis aims to show which benefits occur for different stakeholders when a municipality enhances its services by using IoT and AI with geodata. The enhanced services are either internal or external. Therefore, the benefit will be evaluated by various stakeholders. These stakeholders are the public administration, enterprises, and citizens. In order to answer these questions, an adapted benefit framework was developed out of various already existed benefit frameworks.

The research question will be answered with a case study. The City of Vienna was used as a case, as it has a pioneering role in that field. The thesis analyses the actual and future benefits with expert interviews and documentations of the program "Wien gibt Raum", which consists of mobile mapping campaigns, an internal software (Kappazunder), and a One-Stop-Shop for enterprises and citizens.

2 THEORETICAL BACKGROUND

In order to understand how Vienna is digitizing its services and therefore make it more efficient and more modern, it is vital to understand all the different new technologies used. These technologies combined can make municipalities more proficient and more up-to-date, making their inhabitants' lives easier. For example, they can act online at all times rather than go to the municipality's premises during office hours. As this thesis is focused on Artificial Intelligence, Internet of Things, and Geodata, only these technologies will be elaborated shortly after that. Furthermore, an overview of prior literature on Smart City is given. Additionally, some applications of the mentioned technologies in the Smart City context are given. Moreover, a benefits evaluation framework is created from prior literature to help to define benefits that can be derived from the application of these technologies.

2.1 Technologies

2.1.1 Geodata

Geodata, which can also be called geospatial data or spatial data, is usually described as data about the surface and near-surface on the Earth. Geodata is an observation on which things are present at which locations. As the number of locations is infinite, geodata is often captured in the form of areas, lines, or volumes. There are many different forms of geodata. Geodata can be ground elevation or surface temperature as well as average income and number of inhabitants (Goodchild, 2018).

Geospatial has exact positioning, location details, and either qualitative and/or quantitative information such as geo-referenced satellite images or road networks. Geodata might include further attributes, which in itself describe further attributes found in the dataset. It is either available in a vector or a raster. Vector data consists of at least one node, which determines the location by using two or three axes. Usually, the location is defined by the geographical coordinates and the height from sea level. Raster data usually contains pixels, whereas each pixel covers an area of fixed size. In addition to the area covered by the pixels, it contains the geographical coordinates (Yu & Guo, 2016).

Most geospatial datasets have particular characteristics that classify these datasets to be Big Data. Therefore, it is also referred to as "Geo Big Data" or "Geospatial Big Data". Big Data is often described with a "multi-V model", this model has five specific properties (Yu & Guo, 2016):

- **Volume** – Large size of storage needed
- **Velocity** – Fast arrival of new data and rapidness to respond to processing queries
- **Variety** – Many different data types
- **Veracity** – how much data can be trusted
- **Value** – The financial benefits companies can derive from employing Big Data

2.1.2 IoT

Internet of Things is described as a "things" connected network. The “things” are connected with smart sensors without human intervention and wireless connection. According to Li, Xu & Zhao., the concept of Internet of Things (IoT) was first introduced by Kevin Ashton in 1999, and he referred to IoT as "*uniquely identifiable interoperable connected objects with radio-frequency identification (RFID)technology*" (Li, Xu, & Zhao, 2015)

At first, Radio-Frequency Identifications (RFID) used the technology behind IoT. With further development, wireless sensor networks (WSN) and Bluetooth-enabled devices were able to use IoT technology. The term "Smartness" is usually named as a characteristic of IoT. A "smart" network is usually characterized by the openness and standardization of the communication layers used and a direct IP address and multifunctionality. One example of multifunctionality is that a network built for road traffic monitoring is also available to monitor traffic safety. IoT was an enabler of human-to-machine, human-with-environment, and machine-to-machine interactions (Buyya & Vahid Dastjerdi, 2016).

2.1.3 AI

Many different definitions of Artificial Intelligence (AI) exist, and the first one's dates back nearly 70 years. The European Commission uses a clear and comprehensible definition of Artificial Intelligence, which is as following

> *"Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals.*
>
> *AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications).*
>
> *We are using AI on a daily basis, e.g. to translate languages, generate subtitles in videos or to block email spam.*
>
> *Many AI technologies require data to improve their performance. Once they perform well, they can help improve and automate decision making in the same domain. For example, an AI system will be trained and then used to spot cyberattacks on the basis of data from the concerned network or system" (European Commission, 2018).*

According to IBM, the term AI is broadly applied in the world of technology. It is used to describe solutions that can learn without human interference. The algorithms are able to process a vast amount of data and see trends and reveal insights from that data. These trends or insights are barely possible for humans to find without using these technologies (Ceron, 2019).

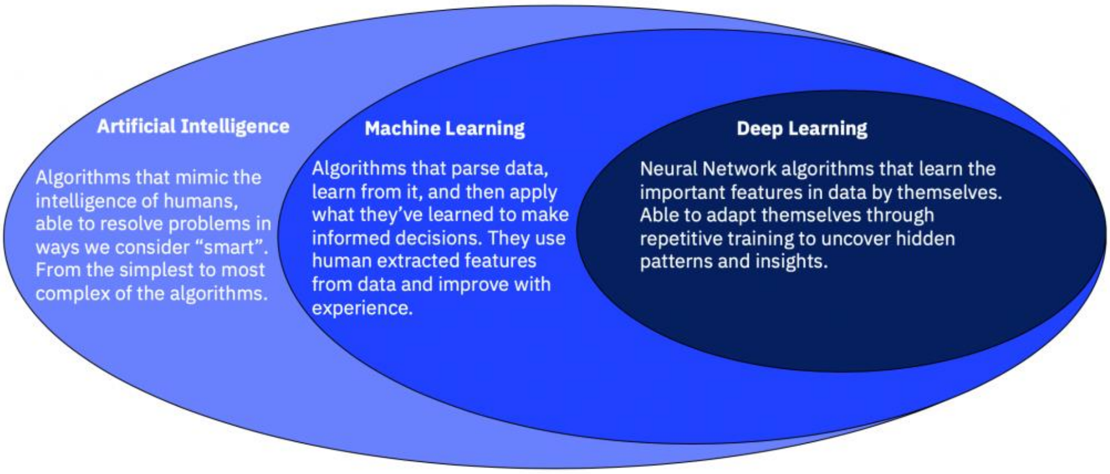

Figure 1: Specialization of AI algorithms. Ceron, 2019

Machine Learning and Deep Learning are often mentioned in the same breath as Artificial Intelligence. Therefore, it needs some more clarification. Machine Learning, as well as Deep Learning, are part of Artificial Intelligence. In Machine Learning, statistical methodologies get applied to identify patterns in past behavior and make decisions. Machine Learning algorithms are good in predicting, for example, predicting the next online purchase of someone or predicting fraudulent behavior. When the algorithm is fed with new data, it will improve over time and get better predictions. These algorithms only explore the data the way they were programmed. Machine Learning algorithms do not adapt their way of looking at data differently. Deep Learning algorithms can learn on their own. Deep Learning means the ability to adapt to different situations or patterns of data. These algorithms can uncover features in data, which they were never programmed to find. This specific behavior is what people usually refer to as AI nowadays. The concept of Deep Learning has been around for a few decades. The weak processing power and the lack of the amount of data have prevented an earlier success of these algorithms. Figure 2 shows that Deep Learning Algorithms became a trend about ten years ago (Ceron, 2019).

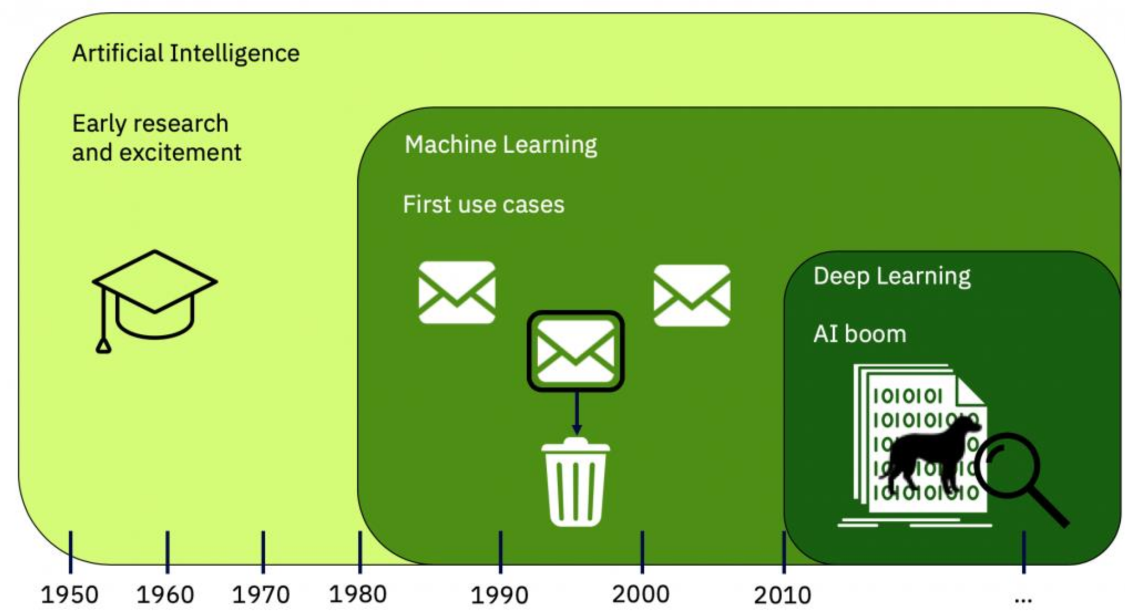

Figure 2: The excitement around AI began a long time ago. Ceron, 2019

Machine Learning algorithms can be categorized into three groups. The groups are supervised, unsupervised and semi-supervised. These three groups are based on the properties, the way the data is used, and the style of learning. Supervised learning algorithms are Logistic Regression, Linear Regression, Support Vector Machines (SVM), Naïve Bayes, and k-Nearest Neighbors. These algorithms have in common that the input dataset has a "true" or "correct" label, and the algorithms are trained with these. In unsupervised learning, there is no explicit training dataset. A goal for unsupervised learning is to find hidden patterns in the data and learn more about the data. Clustering, as well as Vector Quantization, is the most common algorithm of unsupervised learning (Shanthamallu, Spanias, Tepedelenlioglu, & Stanley, 2017).

Also, for Machine Learning the most common algorithms of Deep learning are supervised learning algorithms. A real-world example would be image classification. For the machine to classify images containing cars and houses, it needs to collect an extensive data set of images and each image labeled with its associated category. This dataset is used to train the machine. Another unlabeled dataset is used to test the algorithm. The machine produces an output in the form of a vector of scores, one for each category. The desired category should have the highest score of all categories. (Lecun, Bengio, & Hinton, 2015).

2.2 Smart City & E-Government

The term Smart City was already explained in the introduction from the point of view of the European Union and the city administration of Vienna. As this chapter focuses on academic literature, it will be explained from that viewpoint.

According to Angelidou (2014), a smart city represents a conceptual urban development model. This model is based on the utilization of technological-, collective- and human capital. The utilization will enhance the development and wealth in urban areas. Angelidou mentions that a strategy for smart city development can either be made on a national or a local level. Furthermore, it is stated that the smart city field is still mainly under exploration (Angelidou, 2014).

Albino, Berardi & Dangelico (2015) show that there are many definitions of smart cities. They list 23 different definitions from prior literature. The oldest definition derives from Hall (2000): "*A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens" (Hall, 2000)*

A smart city is often referred to as an intelligent city or a digital city in prior literature, but it means the same. Albinio, Berardi &Dangelico (2015) defined six components (adapted from Lombardi et al., 2012) and related aspects of urban life. These are the following:

- Smart economy: Industry
- Smart people: Education
- Smart governance: E-Democracy
- Smart Mobility: Logistics & Infrastructures
- Smart environment: Efficiency & Sustainability
- Smart living: Security & Quality (Albino, Berardi, & Dangelico, 2015)

Firstly, the most common characteristics of smart cities are a city network infrastructure that allows social-cultural development and political efficiency. Secondly, the natural environment is part of the strategy. Thirdly, social inclusion and social capital. Lastly, business-led urban development and creative activities for urban growth (Albino et al., 2015).

Dameri (2012) developed an evaluation framework for digital cities implementation, which gives a good overview of which actors and stakeholders are involved in implementing a smart city. The framework is defined as a measurement system that is built on three interconnected dimensions.

The actors, as seen in Figure 3, are solution vendors, governments, and education systems. Solution vendors provide the technological solutions to establish a smart city. They see a smart city as a business. Governments define rules, laws, and policies to support smart city implementations. They see a smart city as a driver for the well-being of society. Education systems transfer the knowledge and support the use of a smart city platform as well as the services and professional skills (Dameri, 2012).

Stakeholders are enterprises, public administrations, and citizens. Enterprises use the smart city to improve their productivity for their business activities. They can also use it to innovate their products or services. Citizens are the final recipients of the services from public and private agencies. They gain benefits from a higher quality of these services if they have the possibilities to access them. Public administrations can provide their services with higher efficiency, more transparency, and lower costs(Dameri, 2012).

The framework has three dimensions. These are the conceptual dimension, time dimension, and qualitative dimension. The conceptual dimension has a different meaning for different people. It could mean the technological readiness of a local area, the infrastructure intensity (usage ICT and digital services), the real value for the recipients. The second dimension is the time dimension, and it considers the before-implementation phase, in which the priorities and choices are defined. It also considers the after-implementation phase, in which outcomes need to be measured. The qualitative dimension measures financial outcomes but also non-financial quantitative or qualitative, or intangible benefits (Dameri, 2012).

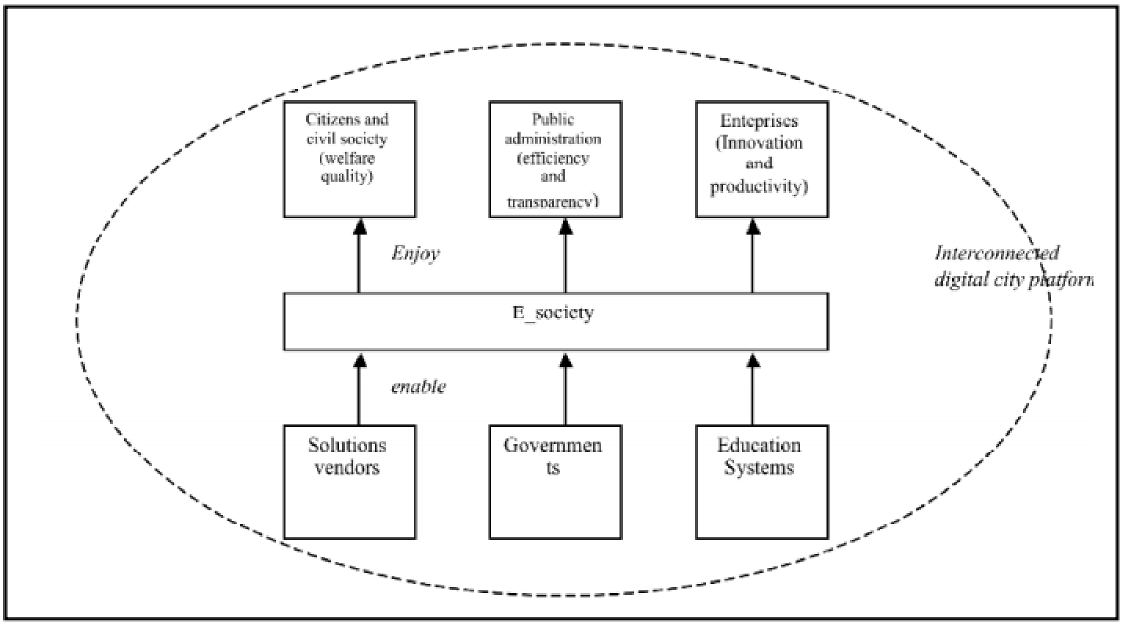

Figure 3: Digital city actors and stakeholders. Dameri, 2012

The described dimensions all need different measurement methods. The main goal of the framework is to support political and technical decisions, which should take all outcomes from actors or stakeholders into consideration. The actors should be able to understand the benefits and returns from the implementation of smart city applications. The stakeholders should create digital service demand to use these services and gain benefits from them (Dameri, 2012).

Dameri (2012) developed a support environment. The evaluation framework should always start with the support environment. The support environment has two dimensions, the horizontal and the vertical. The vertical dimension describes the drivers, offer and demand. The offer drives the applications, but it needs incentives from the market and government policies. The demand is made by the users who request digital services. The horizontal dimension has a pavement and a roof. The pavement is made by government regulations and public policies, promoting and ruling the smart city and its implementations. The roof is made by the digital evaluation system. On the on hand, the before-implementation evaluation to identify expected benefits and priorities. On the other hand, the after-implementation evaluation, which is based on a key performance indicator, helps to rate and understand the outcome (Dameri, 2012).

In order to analyze what makes a city "smart", Gil-Garcia, Pardo, and Nam compared academic literature and six practical tools in 2015. In particular, they compared Innovation cities (IC), Smart Cities -European Medium-sized Cities (EMC), Digital Cities Survey (DCS), Global City Indicators (GCS), UN-Habitat Agenda Urban Indicators (HUI), and Smarter City Assessment Model (IBM model), all ranged from the year 2009 to 2011. It can be argued that the academic literature within this study covered somewhat different areas than the tools. Nevertheless, also, the tools did not all agree on the same things. The findings of this study are shown in Figure 4. There are four major areas that can be improved to make a city smart. These are Government, Society, Physical Environment, as well as Technology and Data, which are broken down into core components. The core components include areas or actions which should be improved to make a city smarter. For example, in order to make the component city administration & management, it should be focused on performance management and e-government. Further examples can be seen in Figure 4. (Gil-Garcia, Pardo, & Nam, 2015).

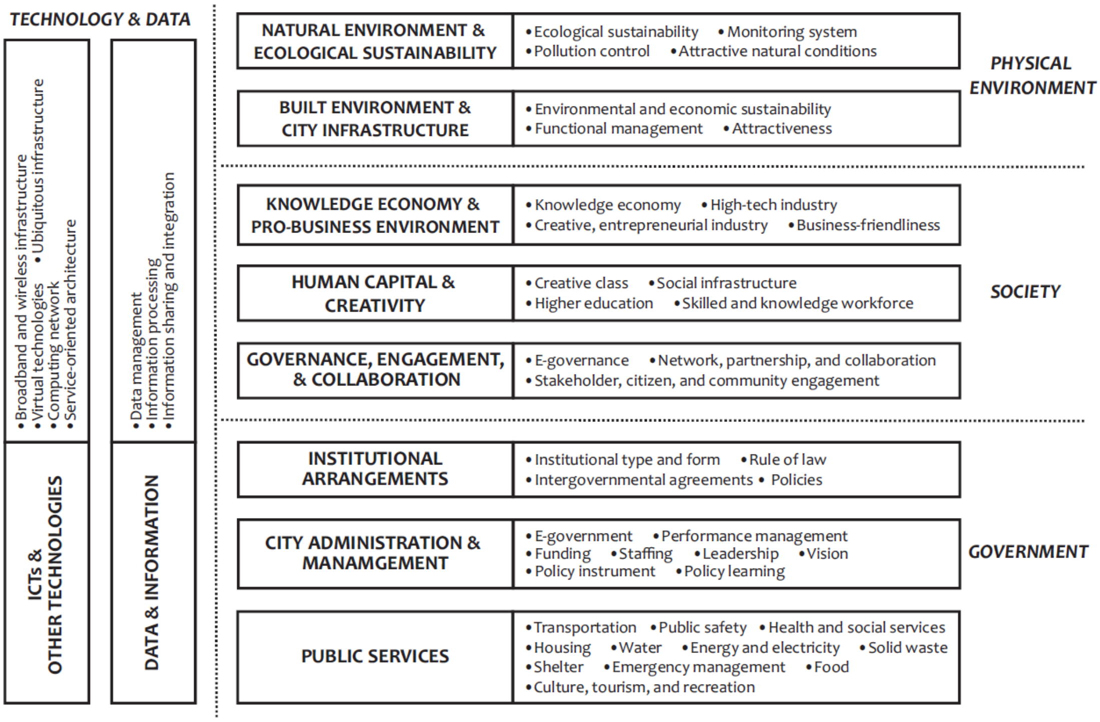

Figure 4: A comprehensive view of smart city components and elements. Gil-Garcia, 2015

McClure (2000), as cited in Layne & Lee (2001), defined the E-Government as an electronic government that uses technology, specifically web-based applications, to enhance its services. It can help build better relationships between the public and the government by making services easier, more efficient and smoother (Layne & Lee, 2001).

Layne & Lee developed a four-stage model for a fully functional E-government. Regardless of the stages, they emphasize that universal access, privacy, and confidentiality, as well as citizen focus in government management, need to be considered while developing E-Government. The focus on the citizens means that the development should not only concentrate on efficiency and effectiveness internally but emphasize improving convenience for citizens. The model is focused on the United States multi-layering of governments (Federal, state, and local). However, it applies to all levels of government. The four stages of e-government are Catalogue, Transaction, Vertical Integration, and Horizontal Integration (Layne & Lee, 2001).

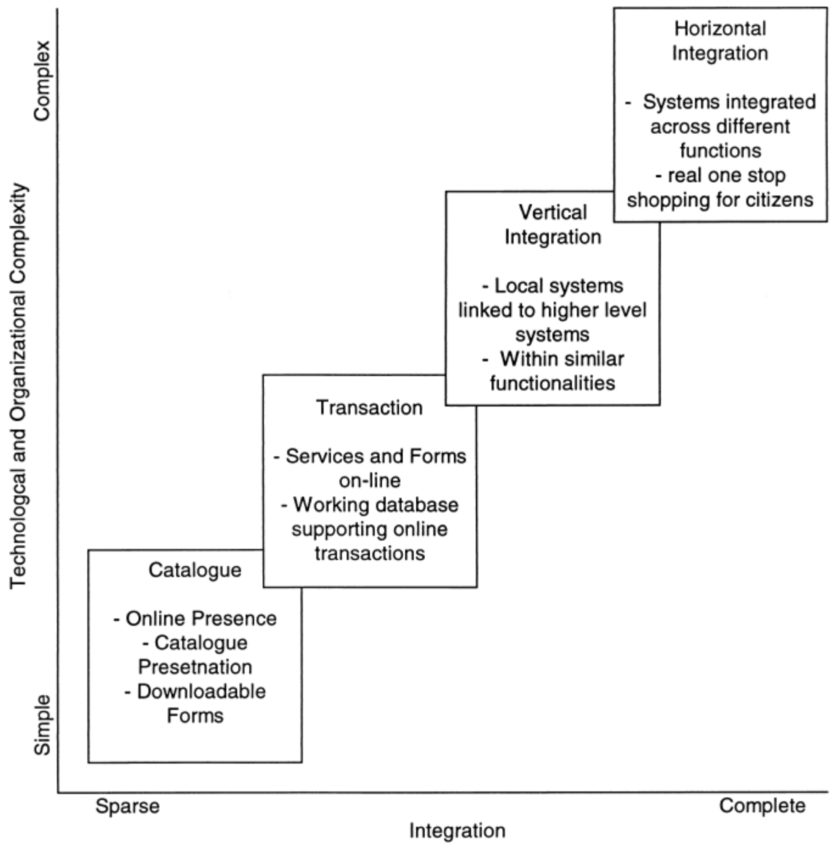

Figure 5: Dimensions and stages of e-government development. Layne & Lee, 2001

The stages seen in Figure 5 by Layne & Lee (2001) will be explained in this part. This model uses Integration and Technological and Organizational Complexity as dimensions. The first stage is called the Catalogue stage. In this stage, the government makes the first steps in going "online". As the internet evolved, more and more private companies had a web presence. So, the citizens expected their governments to be "online" too. The clear benefit for the government is that the time spent on answering fundamental questions which can be answered on their website is reduced. The idea is to reduce the number of phone calls and in-person standing in line. The new functionality for the user is the possibility to search for information on the government's websites.

Secondly, the stage transaction is defined as a stage where the government and the citizens realize the value of the Internet, and the demand from citizens to fulfill government requirements online instead of going to a government's office has risen. The main benefits for the citizens are time savings for doing paperwork or omission of travel time to governments offices. The citizens usually enter through a web portal, which combines the information needed for that service.

Third, vertical integration is focused on the transformation of government services instead of the automation and digitalization of the existing processes. The benefits of e-government will only be realized when technological changes and organizational changes go hand in hand. Agencies maintain separate databases which are not connected to other governmental services. An example would be that a state business license database is not connected with a local business license database. In a vertical integration system of different levels but similar functions will be integrated. In this stage, it is expected that the databases of different levels of government connect or communicate with each other in the same functions.

The fourth stage is horizontal integration. It unleashes the full potential of IT. In this stage, government services are integrated horizontally across different functional silos. Usually, citizens who require a specific service from the government need more than one service. An example is a citizen who requires housing might also require government assistance for education, medical bills, food, and even more services. Horizontally integrated means a one-stop service where this can be obtained in one place. This stage refers to an integrated system across different functions, where a transaction in one agency leads to automated data checks in other agencies. This will facilitate "one-stop shopping" for the citizens. (Layne & Lee, 2001).

Agnihorthri, Sivasubramaniam & Simmons (2002) explained how leveraging technologies could improve the quality of field service. They define two different services, which are facility-based and field-based. For a facility-based service, the customer usually comes to their premises. In the field-based service, it is the service provider's responsibility to provide services to the service receiver or their premises and possessions. The field-based services have three different categories. First, pickup and delivery services. Secondly, emergency services such as police and ambulance. Third, after-sales service support of equipment. Figure 6 shows a customer satisfaction – service productivity relationship connection. The full curve shows what is possible with the current technologies. Ineffective organizations are based inside the curved line. Some organizations might emphasize customer satisfaction, but they might not have high service productivity. To move beyond the solid line and reach the dotted curved line, improvements have to be made. These improvements can only be made through leveraging new information technologies, for example, by deploying a technology-infused service system. This leads an organization with low productivity to gain massive productivity gains, and they find themselves higher on the figure. Examples to improve customer satisfaction with new IT systems are reduced delivery costs, improved employee training, and improved customer service (Agnihothri, Sivasubramaniam, & Simmons, 2002).

Even though this was not designed for the governmental sector, it is still applicable for some parts of the sector as the government has both facility-based and field-based services. Therefore, this figure is valid for some governmental services.

Figure 6: Service productivity customer satisfaction frontier. Agnihothri, Sivasubramaniam, & Simmons, 2002

2.3 Technologies applied in the smart city context

After giving a brief overview of the technologies AI, IoT, and Geodata, as well as smart cities and e-government, all of these topics will be combined. This means in detail that this subchapter explains applications that use these technologies, which can be used in a smart city context for governmental tasks. In total, four applications will be introduced. It is not known if these applications are used by governments. The four applications can be seen in Table 1 and are described thereafter.

Name/Topic	**Use-Case**	**Location**	**Technologies used (relevant for thesis)**
Fully automatic manhole cover detection	Manhole cover Detection with Point Cloud Data	Flemish Region, Belgium	IoT, Geodata, AI
TreeTect	Automated tree detection from satellite imagery	Boston, USA	Geodata, AI
Traffic Sign inventory	Automated traffic sign detection and inventory	Galicia, Spain	IoT, Geodata, AI
Alibaba City Brain	Traffic flow optimization	Hangzhou, China	IoT, Geodata, AI

Table 1: Smart City Applications

The first application in a smart city context is a fully automatic manhole cover detection with point clouds and the usage of neural networks. In the Belgian Flemish region and the Netherlands, accurate and complete spatial databases have been used for several years. Mapping of manhole covers is important as manholes are used for sewage discharge, rainwater collection, telecommunication cables as well as gas/electricity supplies. The data of the manhole mapping can be used to create drainage system models to identify potential high flood risk areas. The data for this case was gathered by a mobile mapping system, which can result in time savings of up to 91% compared to manual surveying. A fully automatic manhole cover detection framework is proposed. With this framework, it is possible to extract manhole covers from the mobile mapping point cloud data. The used deep learning networks only need a small training dataset to achieve considerable good results. The framework resulted in an F2-score of 0.973, which can be considered a good score (Mattheuwsen & Vergauwen, 2020).

A combination of remote sensing and artificial intelligence to achieve Geo AI, which allows detection and classification features faster, is the second application. The application is called TreeTect and is used to accurately and efficiently determine the health of trees and soils in cities. The application is based on a satellite-based standard vegetation index to use timely data on soil health for individual trees. The application also helps to get a digital tree inventory. The application is used as a pilot project in Boston and has identified over 2000 trees in a specified neighborhood in Boston. With the help of TreeTect, the city administration of Boston was able to catalog tree attributes and health (Van Wegen, 2021).

The third application is an automatic traffic sign inventory, which is based on mobile mapping system data. Traffic signs are vital for driver safety. Therefore, governments invest many resources into maintaining the signs – this requires a complete and correct inventory. The application consists of four main processes. The processes are traffic sign detection, recognition, 3-D location, and filtering. In the first two processes, the images were processed by Deep Learning algorithms. A georeferenced point cloud was used for the 3-D location and filtering. The outcome of the application is an 89.7 % correct detection of street signs; 92.5% of them were correctly classified, and 97.5% had a location error of less than 0.5 m (Balado, González, Arias, & Castro, 2020).

The Alibaba City brain was first launched in Hangzhou in 2016. Artificial Intelligence was used from 2017 onwards. The City Brain first utilized data from sensors on cameras and traffic lights. This data from the sensor network is processed by cloud computing in real-time. With the control over the traffic light scheduling, it was possible to optimize transport flows for emergency response vehicles. Version 2.0 of the City brain was updated in 2018, it was added in more areas within Hangzhou, and some other technical expansions were made. One expansion was the direct link to police officers and the ability that City brain could dispatch them to incidents via smartphone alerts. In 2020 the City brain was updated to version 3.0. With this version, the City brain can predict the track of a typhoon before it makes landfall and activates emergency response systems. This version is seen as a digital immunity to natural disasters and pandemics. Alibaba says that the City Brain reduces the transit times by three minutes per passenger journey – increased the average travel speed by 15.3%. Furthermore, the system recognizes 12 distinct events, such as jaywalking and hit-and-runs. The system uses number plate recognition and visual recognition to identify the perpetrators. The accuracy rate is as high as 95%. City brain was implemented in 16 other cities by the end of 2018 (Caprotti & Liu, 2020).

2.4 Benefit Framework

As the research question is focused on the benefits of the usage of the technologies AI, IoT, and geodata, it is important to define what benefits mean. Careful research was conducted to find benefit evaluation frameworks in the Information Systems field. The researched frameworks will be explained in this chapter. As these frameworks do not fit that specific case, an adapted framework was created out of the frameworks found in the literature. This adapted framework will also be introduced in this section

Serra & Kunc (2015) illustrated benefits in Figure 7 below. Stakeholder value is usually delivered by good business strategies. In the public sector, value is created when the organizations provide valuable public services. These business strategies set a desired target in the future. The targets can be met by achieved objectives. The difference between the current situation and the desired target is the value gap, as shown in the figure. This gap is fulfilled by actions and initiatives defined by the organization in the strategic plan. Typically, projects enable positive and defined changes in the organization. The positive changes are strategic improvements which are also known as benefits. These benefits occur for different stakeholders. Usually, the creation of value for an organization strongly depends on programs and projects delivering the expected benefits (Serra & Kunc, 2015).

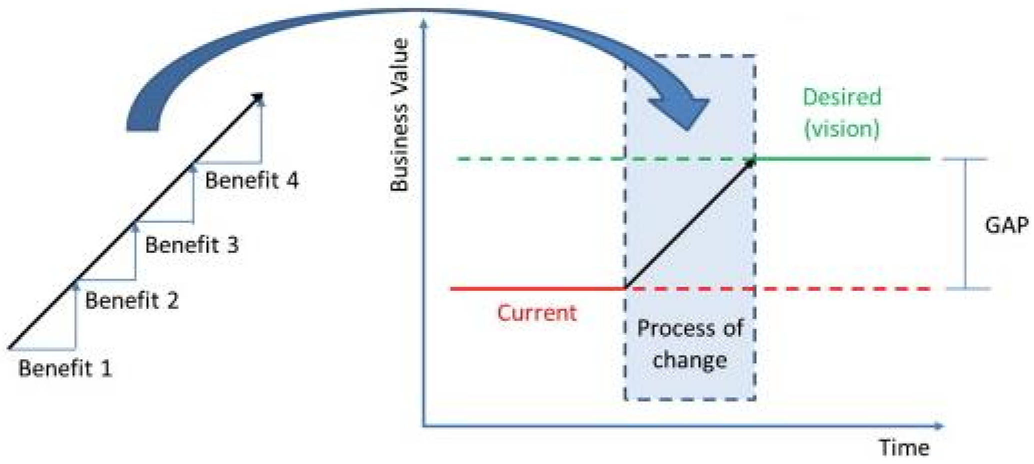

Figure 7: Filling the value gap. Adapted from Serra & Kunc, 2015

According to Scheepers & Scheepers (2008), the benefits of business processes can be divided into initial use, intermediate use, and long-term use. Initial use benefits are usually efficiency gains, which result from the automation of a process. They usually occur shortly after the implementation and can be seen when a new technology replaces a manual process. Examples of initial use benefits are the reduction of errors due to single entry of data and cost savings. Intermediate-use benefits can generally be seen in the following phase. These benefits are created through the new cumulative data. This can be a database of records of customer orders or other data. More available data allows a more informed decision making and can improve managerial control. Long-term use benefits arise from the availability of the data that accumulates over a long period of time. This allows for activities such as data mining or long-term trend analysis. Additional benefits can occur to and from other processes. An example would be that the customer data created from process "X" is used for the marketing and product development processes (Scheepers & Scheepers, 2008).

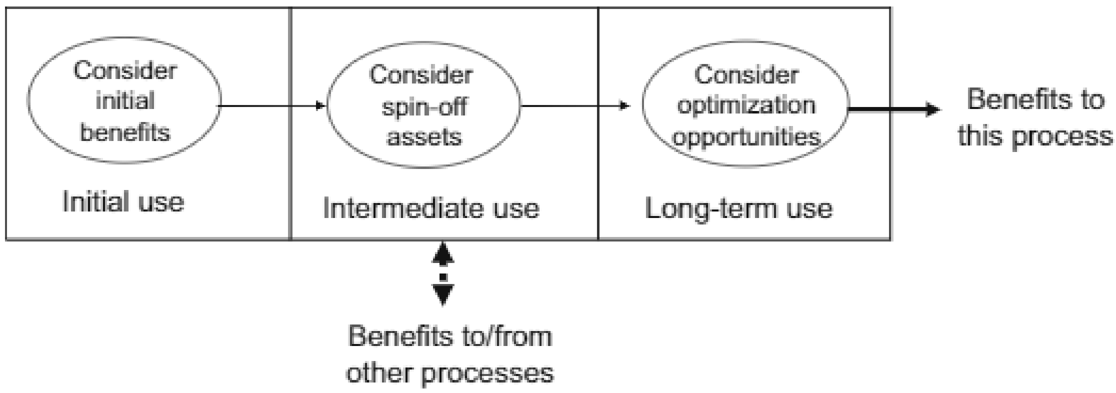

Figure 8: Steps for analyzing benefits that accrue from IT use in a particular business process over time. Scheepers & Scheepers, 2008

DeLone & McLean (1992) created a framework that identifies factors that contribute to the success of information systems. In order for information systems to make an impact on real word practices, the outcome needs to be measured. DeLone & McLean studied a wide field of previous IS research that focused on measuring the outcome of IS implementations. They combined these findings into one framework of six specific categories to evaluate the outcome of Information Systems. These are System Quality, Information Quality, Information Use, User Satisfaction, Individual Impact, and Organizational Impact (DeLone & McLean, 1992).

The category System Quality aims to evaluate the processing system itself. Information Quality focuses on the information system output. More specific the quality of the information produced by the systems. Information Use is described as the recipient consumption of the output of an Information System. The category User Satisfaction means the recipient responds to the use of the output of an Information System. Several IS researchers have decided to include user satisfaction in their success measures. Individual Impact is described as the effect of information on the behavior of the recipient. It is mentioned that this factor is probably the most difficult to define in a non-ambiguous way. Organizational Impact is described as the effect of information on organizational performance (DeLone & McLean, 1992).

The described categories and some selected evaluation measurements can be seen in Table 2.

Category	System Quality	Information Quality	Information Use	User satisfaction	Individual Impact	Organizational Impact
Evaluation criteria	Data accuracy Ease of use Ease of learning Convenience of access Realization of user requirements Usefulness of system features and functions System accuracy System reliability	Importance Relevance Informativeness Readability Understandability Appearance Accuracy Comparability Completeness	Amount of use Number of functions used Frequency of access Number of reports generated Regularity of use	Overall satisfaction Satisfaction with specifics Information satisfaction Difference between information needed and received Decision-making satisfaction	Information understanding Accurate interpretation Problem identification Decision effectiveness Decision quality	Application portfolio Range and scope of application Operating cost reductions Overall productivity gains Return on investments

Table 2: Categories and Evaluation criteria. Adapted from DeLone & McLean, 1992

In 2003 DeLone and McLean released a ten-year update of their Information Systems success model from 1992 with some important changes. The model was extended by the measurement of Service Quality. As in the previous research, there was no focus on service, this was added. The instruments to measure service quality include (DeLone & McLean, 2003):

- Tangible
- Reliability
- Responsiveness
- Assurance
- Empathy

Instead of individual and organizational impacts, DeLone and McLean (2003) use the measurement Net Benefit. The reason for that change was that the previous categories, individual impact, and organizational impact did not include impacts for groups such as workgroups, industry, consumer, or inter-organizational impacts. Instead of complicating the model with even more success measurements, net benefits were introduced to have a measurement for all impacted groups. The measurement net benefits can be defined as the most important and most accurate descriptor of the final success variable. In order to find answers for the category net benefits, it needs to be defined on which group net benefits are focused, as these benefits could occur for many different groups. For example, the benefits for a sponsor are different from the benefits of a user. As this measurement is so diverse, the focus on the groups needs to be determined by the context and objective of the study that uses this framework (DeLone & McLean, 2003).

Shang and Sheddon (2000) described a comprehensive framework for classifying the benefits of ERP Systems. The application described in the Case Study, which follows in this thesis, cannot be classified as an ERP System. However, the benefits framework is very compact and also applies. The author of this thesis decided that parts of the Shang & Sheddon (2000) paper are a good fit to analyze the benefit for IT Systems from organizations. Only the parts which are used for the adapted benefit framework will be explained.

Shang and Sheddon (2000) described five dimensions that were developed for an organization's senior management to classify the benefits of ERP-System implementations. The dimensions are operational, managerial, strategic, IT Infrastructure, and Organizational (Shang & Seddon, 2000).
In Table 3, the Dimension and Subdimension for classifying benefits can be seen. The dimension Organizational is not included, as it is not part of the adapted benefit framework by the author of this thesis.

Dimension	**Operational**	**Managerial**	**Strategic**	**IT Infrastructure**
Subdimension	Cost reduction	Better resource management	Support business growth	Support organizational changes
	Cycle time reduction	Improved decision making and planning	Support business alliance	Facilitate business learning
	Productivity improvement	Performance improvement	Build business innovations	Empowerment
	Quality improvement		Build cost leadership	Built common visions
	Customer services improvement		Generate product differentiation	
			Build external linkages	

Table 3: Parts of ERP Benefit Framework. Shang & Seddon, 2000

After explaining some prior literature to benefit frameworks, an adapted framework, which can be seen in Table 4, is introduced. The following framework was adapted by the author of this thesis to fit the context of this study. The first column, Stakeholder, was previously explained and originated from the evaluation framework for digital cities implementation from Dameri (2012). The column stakeholder uses the same classification stakeholder, which are enterprises, public administration, and citizens as described by Dameri. The second column is used to categorize the benefits. The categories used in this adapted framework are taken and combined from different sources. System quality, Information quality, Information use, and User satisfaction were first mentioned in DeLone & McLean (1992). Service quality and Net benefits were described by DeLone & McLean (2002), whereas Net benefits are used as an umbrella term for individual benefits and organizational benefits. In DeLone & McLean (1992), there was no umbrella term but rather individual and organizational impacts. The author of this thesis decided to change the word implications to benefits, as implications allow both positive and negative outcomes. Whereas benefit only has positive connotations. The classification individual implication was previously used by DeLone & McLean (1992); however, this thesis uses the classification individual benefits, which is completely new. The individual benefits measure the benefits for individuals. This could be enterprises, citizens, research institutes, a specific group of employees within the public administration, or similar. The classification organizational benefits has its origin in DeLone & McLean (1992). However, it does not use the evaluation measurements provided by this thesis. Instead, it uses the measurements operational, managerial, strategic, and IT-Infrastructure from Shang & Sheddon (2002). The last column, Time / Use, originated in a paper by Scheepers & Scheepers (2008). With the help of the framework, it is possible to describe if the benefit occurs immediately after implementation or later. This was described previously and consisted of initial use, intermediate-use, and long-term use benefits. The combination of these different frameworks into one adapted benefit frameworks makes it possible to have a great foundation to analyze the findings of the following case.

Stakeholder (according to Dameri, 2012)	Benefit evaluation (adapted from Shang & Sheddon, 2002. DeLone & McLean 1992; DeLone & McLean 2003)	Time/ Use (Scheepers & Scheepers, 2008)
Enterprises Public administration Citizens	System quality Information quality Information use User satisfaction Service quality **Net benefit** • Individual benefits • Organizational benefits ➢ Operational ➢ Managerial ➢ Strategic ➢ IT Infrastructure	Initial use Intermediate use Long-term use

Table 4: Adapted Benefit Framework

3 METHODOLOGY

The chapter Methodology will elaborate on the underlying literature for the research approach, the way of data collection as well as the analysis of the data. It will illuminate which method was used, either quantitative or qualitative methods or a mixed method. This section will also clarify which research method was chosen, such as Case Study or Design Science Research.

3.1 Research Approach

The research of this thesis will be elaborated hereafter. Firstly, the purpose of this thesis is to show which benefits emerge for stakeholders of smart cities while they enhance their services with the technologies of IoT, AI, and Geodata. This will be elaborated on the Case of the City of Vienna. This thesis is a qualitative research as it focuses on gaining a new in-depth understanding of the mentioned subject by conducting interviews, analyzing reports, and strategy papers.

According to Denzin & Lincoln (2005), a generic definition of qualitative research is:

"...a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them." (Denzin & Lincoln, 2005)

Referring to Eisenberg and Graebner (2007), an inductive study consists of a significant research question and a clarification of why prior literature was not feasible to answer the research question. The prior literature is either unable to answer the research question, or the outcome will be inadequate or likely to be untrue (Eisenhardt & Graebner, 2007). The inductive study design was chosen because there is a gap in the existing literature on this specific topic. Furthermore, the research question is significant as it shows a real-world case, and this case is very innovative as a whole. Therefore, an inductive approach was seen as suitable for this research.

This thesis follows the methodology of a case study as a research strategy. According to Yin (2003), a case study is an empirical inquiry that examines a phenomenon in a real-life context, particularly if the borders between the context and the phenomenon are not obvious. Furthermore, a case study research approach copes with an extraordinary situation with many variables. It relies on more than one source and needs data to converge a triangulation. A case study research approach benefits from prior theoretical suggestions to guide the collected data and the analysis of those (Yin, 2003).

A case study can either be designed as a single-case study or a multiple-case study. A single-case study is an appropriate design if one of five rationales applies. These rationales are a critical case, an extreme or unique case, a representative or typical case, a revelatory case, and a longitudinal case (Yin, 2003).

This thesis is a single case study because it is a unique case. As Vienna is in a pioneering role in the field regarding the research questions and it offers public documentation about the case as well as coherent strategies. Therefore, it is a good fit to create a case study about it. Some other cities might use these technologies in another context or use them in a similar or lower context but do not publish data, which makes it impossible to find and evaluate.

According to Robson (2002), research can follow three distinctive purposes. These are either exploratory, descriptive, or explanatory. Exploratory studies focus on the exploration of a real-world problem. Most real-world related research questions are either exploratory or descriptive focused. Robson gives examples of research questions for all of the three mentioned purposes. Flexible qualitative studies are appropriate for the questions focused on exploration (Robson, 2002).

This thesis has an exploratory research approach, as there is a lack of prior literature which is specified on this topic. This is especially true because Vienna is in a pioneering role in this field. Therefore, this thesis focuses on exploration on the already mentioned research question: "How can municipalities benefit by using IoT, AI, and Geodata to enhance their services? The Case of the City of Vienna". This exploratory study aims to clarify how Vienna, its Citizens, and other stakeholders benefit from this innovative usage of mentioned technologies. The next subchapter data collection will clarify on which data the empirical part is based.

3.2 Data collection

As this thesis uses qualitative methods, interviews with experts relevant to the research question were conducted, and the collection of existing data was done. The existing data was either found independently online, or the materials were recommended by some interview partners or employees of the City of Vienna. All of these materials are publicly accessible from the internet, so no internal materials were used for this thesis. For further understanding, the author got access to the software Kappazunder which is explained in the case-specific chapter. However, no data or personal experience from this test will be included in the thesis. In order to explain it, only publicly available data will be used.

The interview partners were recommended by an employee of the City of Vienna, who made his expertise and network available for this thesis. The interview partners were approached either via E-Mail, via internal chat software, or by phone. All interviewees either directly work for the city administration or for companies that are very entrenched with the City of Vienna and collaborated on the matter of this research thesis. The interviews were all carried out in May 2021. Due to the Coronavirus, all interviews were held online via the videoconference software Zoom or internal videoconference software. The interviews were recorded with the integrated function of the videoconference tool. Furthermore, a backup recording was made via audio recording on a mobile phone. All interviews were conducted in German. They were first transcribed to Microsoft Word and copied to Excel. In Excel, the results were further analyzed in German. The relevant parts, which are used in the thesis, were translated to English. The interviews followed an interview guideline which was prepared with the guidance of the thesis supervisor. The interview guideline is attached in the Appendix in German and in English. All interview partners, their position, the time and place of the interview as well as the duration are further elaborated in Table 5.

Interview number	Name (sorted by surname)	Position; Department	Time & Place	Duration
1	Lothar Eysn	Co-Head of the Department & Head of Innovation in IT; Surveying and Mapping – MA 41	11.05.2021 Online	1 hour
2	Matthias Griessenberger	Program Manager “Wien gibt Raum”; Legal Affairs: Transport and Traffic – MA 65	07.05.2021, Online	45 minutes
3	Christian Habernig	Head of IT Innovation; Vienna Digital – MA 01	11.05.2021, Online	1 hour
4	Sandra Heissenberger	Chief executive security officer; CIO Office – MD-OS	06.05.2021, Online	35 minutes
5	Nikolaus Summer	Senior Expert Smart City Agency; Urban Innovation Vienna	10.05.2021, Online	1 hour 15 minutes

Table 5: List of Interviews

According to Robson (2002), an interview can follow three distinct types. Either a structured, unstructured, or semi-structured interview type. The fully structured interview has pre-determined questions with a fixed wording. It is similar to an interview-based survey questionnaire. In an unstructured interview, the interviewer lets the conversation develop within a predefined area. The unstructured informal is completely informal. The semi-structured interview is based on an interview guide that works as a checklist of topics that should be covered within the interview. Additional unplanned questions can be asked to follow up on what the interviewee answers (Robson, 2002).

A semi-structured interview type was chosen for this study. The reason for choosing a semi-structured approach was that all interviewees have different positions and expertise. Therefore, a fixed set of questions without a fixed setting was not seen as a good fit. An unstructured interview has not seen as appropriate because it will not give the best outcome to answer the research question.

3.1 Analysis of the data

Yin (2003) explains five specific analytic techniques. These are explanation building, pattern matching, logic models, time-series analysis, and cross-case synthesis. The beginning four techniques would be suitable for a single case study. Yin states that most case studies analyze use pattern-matching logic. Pattern matching aims to compare the empirically based pattern with a predicted one, such as a theory or a hypothesis (Yin, 2003).

In this thesis, the theoretical framework was written before the empirical part. In the theoretical part, an adapted benefit framework was developed with the usage of already existing frameworks to fit the case. This adapted framework was used to analyze the interviews. The first order coding included the benefits mentioned for the different stakeholder groups, which were defined as City Administration, Citizens, and Enterprises. An additional Stakeholder group was added as some interviewees have expressed the urgency for "Research Institutions" to be a stakeholder group as well. Therefore, it was added even though it is not in the literature review. After finishing the first order, a second-order coding was done. The codes for this were "initial-use", "intermediate-use" and "long-term-use". This allows conducting a throughout analysis of the interviews. The gathered results are shown in chapter 4. The most relevant findings from the interview are then compared to the described adapted benefit framework in chapter 5.

4 CASE CITY OF VIENNA

In this chapter, the focus lies on the City of Vienna. First, Vienna's Smart City Strategy, Digital Agenda, IoT, and AI Strategy will be explained as these are very important for the development of a smarter city with enhanced services for its citizens and businesses. Secondly, the program "Wien gibt Raum" will be illuminated. The program includes the mobile mapping campaign, the internal software "Kappazunder" and a One-Stop-Shop. Each part will be clarified. Thereafter, the results of the interviews with experts mentioned in the previous chapters will be explained.

4.1 Vienna's Strategies

Roland Bergers' "Smart City Strategy Index 2019" study has shown that only 153 cities have published a Smart City strategy, whereas only eight cities have a good strategy and strong implementation to build a Smart City. According to Think: Act, the key to build a smart city is a strategic approach. They compared these 153 strategies and found that Vienna has the most comprehensive Smart City framework strategy, which is complemented by a digital agenda. These strategies are freely available to download on their homepage. In 2019, Vienna, Singapore, and London were on the highest level and the only cities that were on the advanced level of implementation. The implementation attributes are high capability, broad project scope, completed or active status, and full results tracking. Vienna leads in implementation, especially in the field of E-Health, Open Public Data, and Virtual Office (Roland Berger, 2019).

Since Vienna is always ranked very high in most Smart City indexes or even leads them, Vienna seems to take a pioneering role. So, the smart city strategy is being closely scrutinized. The City Administration developed this "Smart City Wien Framework Strategy" first in 2014 but adjusted it in 2019. It is very ambitious that the City of Vienna defines its Smart City Strategy from "2019 – 2050". This shows that there is a clear goal and a "big picture". This timeframe also gives the people, which are usually resistant to major changes, enough time to adapt to them.

The Strategy states that: *"Vienna's definition of smart means amalgamating innovations and new technological and digital capabilities, climate action and resource conservation, high social standards and opportunities for participation into an overall vision that inspires people and prompts desire for change."* (City of Vienna, 2019c)

The Smart City Wien Framework Strategy includes 12 thematic fields. However, this thesis only focuses on the field of "Digitalization". It is worth mentioning that the strategy is based on the 17 "Sustainable Development Goals" (SDGs) by the UN 2030 Agenda.

A goal of the Smart City Wien Framework Strategy is that Vienna will be the innovation leader by 2030, and another goal is that Vienna is Europe's digitalization capital. In order to improve the quality of life, digitalization is seen as a tool to do that. Therefore, digitalization is steered in all areas to benefit the Viennese people. Public data (open government data) and digital platforms, as well as communication channels, are used to increase public participation and engagement. Especially, open government data allows companies to develop innovative applications for the Viennese population. This means that Vienna will have a broad range of digital applications, which will become part of everyday life for many people. Hence, Vienna promotes a culture of innovation. The strategy clearly emphasizes that it is centered on the people (City of Vienna, 2019c).

For the field "Digitalization" Vienna sets seven objectives, the three which are most relevant for this thesis are:

- The usage of digital data, tools, and Artificial Intelligence in applications that maintain a high quality of life and help conserve resources
- By 2025, all processes and services of the municipal administration and its associated enterprises should be digitalized and fully automated when possible
- Usage of digital data (mined with state-of-the-art technologies) to support decision-making and for real-time management of urban systems (City of Vienna, 2019c).

The Smart City Wien Framework Strategy is basically an umbrella strategy, which combines many other strategies. The one which is most relevant for this thesis is the "Digital Agenda Wien". The Digital Agenda Wien is a publication that shall help Vienna to become Europe's digitalization capital and was first released in 2014 and then adapted in 2019.

Some of the objectives of the Digital Agenda Wien are:

- Long-term strategic control of change processes to become the digitalization capital
- Best usage of new technologies to achieve the Smart City Goals 2050
- Strengthening the fast-growing ICT sector while ensuring social fairness
- Participation and involvement of the Viennese population in the digital services
- Leveraging tremendous opportunities for the digital city administration

The Digital Agenda Wien elaborates a "to-do list", which will help to have a successful digital transformation. A special focus lies on digital humanism. This means that the focus is human-centric. The main goal is that the new technologies serve humans and not the economy. A further focus of the digital agenda is that digitalization is also powered by participation. Vienna created a platform where everybody can discuss ideas and opinions on topics regarding digitalization, so they started topics on how the Internet of Things and Artificial Intelligence could be used in the city. Through this participation platform, they gathered valuable input, which is also reflected in the Digital Agenda Wien (City of Vienna, 2019b).

The Digital Agenda Wien states that in order to become the capital of digitalization, the City of Vienna still needs improvements in some fields. Therefore, they selected various fields of action and explained the objectives and the projects which they work on in the respective field. The action fields for Vienna according to the Digital Agenda Wien are:

- Security
- Service
- Knowledge
- Industry 4.0
- Economy
- Infrastructure
- Control

The action field "Security" focuses on reliable and safe IT infrastructure, data security, undisrupted services, defensive and preventive measures for cyber threats. Service focuses on a "City as a Service" principle, optimization of all services, implementation of service-oriented state-of-the-art GovTech solutions, as well as the consideration of the opinions of their citizens. The action field "Knowledge" puts its attention on the modernization of Vienna's educational institutions, promoting a digital focus in education and training, create easy access to knowledge and databases as well as encouraging creativity and space for experimentation with new technologies. The field industry 4.0 wants to offer digital training for all Viennese people, strengthen brick and mortar shops to go online, creating legal certainty of sharing economy, and harmonize the balance between work and family with new technologies. The economy concentrates on attracting international IT companies as well as startups to strengthen Vienna in specific areas like the international gaming industry and further expand their network for innovation drivers. The goals for the field infrastructure are the improvement of the digital infrastructure, the effective and secure usage of natural, technical, and human resources, enhancements of Vienna's services, improvement of the participation of Viennese people, and ensuring barrier-free access. The last action field is controlled, the targets for control are to implement a dynamic IT strategy, to further develop the CIO office, which operates as a think tank, to nominate a "Digital Officer" in each municipal department, to have modern IT equipment, use the main partner "Wien Digital" for operational implementation (City of Vienna, 2019b).

As this thesis is also based on Artificial Intelligence, Vienna's "AI Strategy City of Vienna" has to be mentioned. The AI Strategy is part of the Digital Agenda Wien and was also released in 2019. The strategy clearly states a vision and mission, which is that all areas of the city administration could benefit from the usage of artificial intelligence. AI will increase efficiency and create new possibilities through automation and process support. The usage of AI methods in collaboration with companies or startups will benefit Vienna as a business location. The AI Strategy of Vienna states eight strategic goals. First, to enhance the services for Viennese people, the full potential of AI has to be unleashed. Secondly, the usage of artificial intelligence will improve the user experience of the city's services. Third, sustainable, recyclable, and universal deployable AI basic infrastructure components should be used. Next, case studies and generic application scenarios provide an overview of the reasonable and appropriate use of artificial intelligence. Fifth, for the employment of AI technologies, the market maturity, as well as security, availability, stability, and functionality, will be taken into account. Furthermore, decisions are not made by a machine - decision-making is still the task of humans. Lastly, the development of AI applications will be carried out in collaboration with companies, startups, and research institutions (City of Vienna, 2019a).

Another Strategy paper that is relevant for this thesis is the "Internet of Things-Strategy", it is also part of the Digital Agenda Wien and was released in 2018. The IoT Strategy explains some use cases where the IoT technology is already used. It emphasizes again that the strategy is human-centric and that through citizen participation processes and other sources, 130 potential application cases were drawn up. These have been examined in more detail. To see if the application cases are suitable for a city like Vienna, the City Administration developed an evaluation matrix with eleven general and seven technology sequence criteria classifications. After the assessment with the evaluation matrix, further interviews with the responsible municipal departments were held. These interviews aimed to get general ideas for IoT and input on specific cases from the municipal departments. After the analysis of these interviews, a final evaluated catalog of ideas was made. For the ideas on the catalog, a possible implementation was planned. They were listed and ranked with points from the evaluation matrix and inputs from the interviews. The strategy further discusses the IT architecture as well as platform reviews and a roadmap (Stadt Wien, 2018).

4.2 Documentation of the Case

This subchapter is focused on the analysis of documents from the City of Vienna. The documents provide an in-depth look at a program that used the technologies IoT, AI, and Geodata to enhance their services. These documents explain one specific project. The project is called “Wien gibt Raum”. For this project, the first mobile mapping campaign was realized in 2017. This mobile mapping campaign was a high-resolution record of all streets in Vienna. The data, which was generated from these recordings, were then processed and made available in a viewer software called “Kappazunder”. Furthermore, the data gathered is used for the One-Stop-Shop solution “Wien gibt Raum”. The “One-Stop-Shop” is intended to serve as the single point of contact for many different applications, and it aims to simplify processes for customers and the city administration. The documents used for this subchapter are all publicly available on the internet.

The importance of the public space is emphasized in a special concept for public space, which refers to public space as a “mirror of social dynamics, urban change and as a venue for urban culture”. The public space in Vienna should be available for all Viennese people, and it should be a place of participation and inclusion. An essential factor while using and administering the public space are the objects (so-called street furniture) that are or will be placed there. These objects can be bicycle stands, newspaper collection boxes, advertising signs, seating furniture, fountains, kiosks, or street cafes. Before starting the project, it was estimated that more than 300.000 objects are placed in the public space. The City of Vienna has many different municipal departments which are responsible for these objects. They were all administered in different methods like different IT-Systems, databases or they used different interfaces. Furthermore, for some services, it was necessary to arrange site inspections. The program “Wien gibt Raum” reorganizes some responsibilities in the city, such as the administration of objects and activities in the public space. A new customer interface serves as a digital and physical One-Stop-Shop. For that reason, some internal processes had to be reorganized. The main goal of “Wien gibt Raum” is to simplify the usage of public space for citizens and businesses. Software is used to merge geodata, surveying, and image data with existing permits and applications data. This enables the participating municipal departments to network better. The advantage for citizens and companies is that they have a single point of contact for their concerns and permits from either a physical or digital One-Stop-Shop (Strondl et al., 2018).

Moreover, the City of Vienna obtains an overview of the objects being located in the public space. This is the foundation for decluttering it – in other words, clearing out illegally placed objects, therefore, create more public space for everyone with a focus of fair use for all (Strondl et al., 2018).

The foundation for many steps in the program was a survey of the existing objects in the public space through a mobile mapping campaign. A mobile mapping campaign created an image of the city, which is subsequently used for the 3D extraction of features in the public space. Objects of the public space can be described on a denoted object catalog in order to be located in the image data and added to street furniture specific GIS (Geographic Information System) layers. These layers build a foundation for the visualization of inventory and approval data in the IT systems as well as for monitoring processes for the city administration. These image data from the mobile mapping campaign will be given to the employees of the City of Vienna through a web-based image data service (Kappazunder). The service can be used for digital site inspections instead of a physical inspection, but also statements can be carried out digitally. This saves time and costs. The mobile mapping was carried out by a third-party company, and the requirements for the campaign were that about 3000 km of street network needed to be covered. Furthermore, vision sensor technology with a panoramic camera, high-resolution image data, Georeferencing with absolute 10 cm and relative 5 cm accuracy were necessary. Additionally, complete anonymization of persons and vehicle license plates was obligatory. In total, approximately 3000 km of road network in the 415 km² urban area of Vienna were covered. This has required a travel distance of 4200 km as all lanes, oncoming traffic, and turning lanes had to be considered. The mobile mapping was carried out by two identical survey vehicles equipped with a Global Navigation Satellite System (GNSS), a Receiver Inertial Measurement Unit (IMU), three RGB stereo camera systems, one RGB panoramic camera, and one rear-facing RGB mono camera. The cameras trigger approximately every 3 meters, depending on the situation. The first part of the mobile mapping campaign was carried out from September 2017 – November 2017. In total, 17 million images with a size of 35 Terabytes were gathered. The campaign was continued from March 2018 – May 2018. In order to process the raw data, some steps had to be taken. First, the data had to be transferred into a processing cloud where the following steps, the georeferencing, segmentation of the recorded sections, quality check of the calibration and segmentation, processing, and anonymization, were done (Strondl et al., 2018).

Figure 9: Vienna's road network and mobile mapping car with different cameras (Eysn & Falkner, 2019)

Figure 9 shows the road network of Vienna and the cameras on the cars used for the mobile mapping campaign. As mentioned, the data gathered through this mobile mapping campaign is used by the internal software Kappazunder. The software is a web solution, and it is connected with the geodata infrastructure (GDI) of Vienna. Therefore, feature classes can be implemented. Furthermore, it is possible to create new feature classes. The digitized geodata can be further used for various applications and GIS analyses. The main goals of Kappazunder are the digital inspections of different locations and an efficient evaluation of 3D objects through the interpretation of features in the image data. Further possible use was found to be an inventory tool for objects. The collaboration of different municipal departments has created two new pilot projects. The first project's aim was to create a complete inventory of all types of advertising media. This data creates a good foundation for new advertising concepts in the city. The second project’s goal was to get more precise data of all traffic signs and signposts. These data already existed, but the quality was inaccurate. A complete inventory of about 100.000 locations was created. These data were then linked to the old data from another system due to legal reasons. In both projects, a precise definition of all objects was needed. Therefore, an object catalog for the first project defined 20 different groups of objects such as advertising pillars, bill-boards, or rolling boards. For the second project, the objective catalog was focused on the definition of traffic signs and signposts, which are in the administrative area of the City of Vienna (Eysn & Falkner, 2019).

The inventory was made in the software Kappazunder. Employees drove virtually on the road network and marked the objects with digital tools within the software. The result of the processing is high-quality 3D geodata, which is stored in the GDI. Within two months, the inventory for project one with roughly 32.000 objects was finished. The accuracy was better than 10 cm, and the created data can be pictured not only in Kappazunder but also on the orthophoto (aerial photo) of Vienna. An error rate of 5% was counted. This was attributed to several factors, such as wrong classification or evaluation error. Due to the successful evaluation, the City of Vienna can now rely on an excellent data basis of all visible advertising media. In Figure 10, a section of a density map of advertising media in the road network of Vienna can be seen. This map uses the data which was created as explained. This map allows a throughout analysis of various contexts. Streets with the color yellow have a high density of advertising media, whereas purple streets have a low density (Eysn & Falkner, 2019).

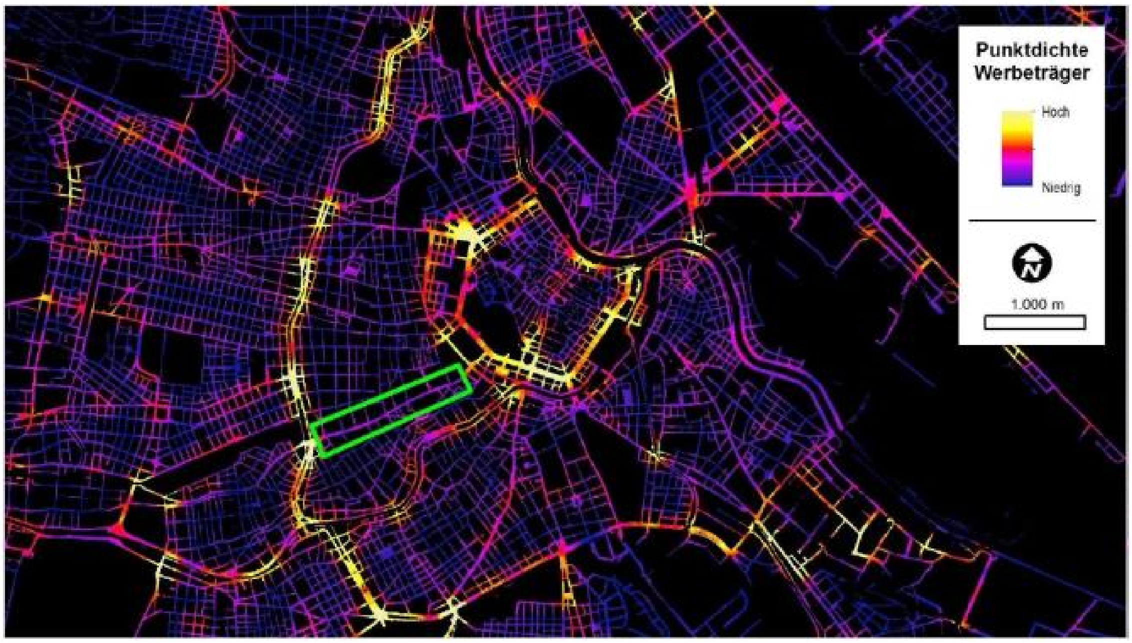

Figure 10: Section of a density map of advertising media in the road network of Vienna. Eysn & Falkner, 2019

The second project was, as mentioned, the inventory for traffic signs and signposts. The main challenge was to link the old data, which only had addresses as a location, with the new precise data. The old data was very unprecise as an address for a specific property can be very long, and traffic junctions have no precise spatial reference. This was done manually, like in project one. Additionally, the data was connected to the old system and linked to the old data. 18% of the inventoried traffic signs had no legacy data, so they had to be newly created in the old system (Eysn & Falkner, 2019).

Kappazunder makes simple viewing of images or more complex processing possible. To ensure up-to-date data, further surveys are planned at regular intervals. So far, the data is only available for the road network. Further data gathering to areas such as bike lanes, parks, or the “Donauinsel” might be possible in the future. The two presented projects have shown that high data quality and accuracy can be achieved with the tool. For future projects, it is planned to use feature extraction from the image data based on a deep learning approach. These deep learning methods and the integration of laser scanning could allow the detection and inventory of simple objects such as manholes or poles (Eysn & Falkner, 2019).

In 2020 a second mobile mapping campaign was started. This time a panoramic camera system captured imagery, and a Lidar system captured 3D information. The data gathered in 2017 was used to test an image-based artificial intelligence. In a first proof of concept, traffic signs were automatically determined from the data. Two different neural networks were trained and applied. One neural network was responsible for the feature detection and the other one for feature classification. The potential of this technology was rated very high as the completeness and correctness of the outcome can be higher than 95%. Additionally to the mobile mapping campaign in 2020, an aircraft-based mobile mapping system that captures nadir and oblique images covered the whole city with aerial imagery. Both data, the mobile – and aerial mapping campaign, can be a sufficient input for applications of an artificial intelligence framework, which is currently developed. The future intention of the artificial intelligence framework is that it will be an automated method for updating different geodatabases, which will be the input data for a digital twin of the City of Vienna in the future (Eysn, 2020).

As the documentation is not focused on explaining the usage of the technologies IoT, AI, and Geodata but rather the program in general, a short summary is given of how this technology is used. First, Internet of Things is used in the gathering of data when different sensors and cameras are connected to create the images. Second, Artificial Intelligence is used to process these images, as because of data protection, faces or license plates have to be unrecognizable. Therefore, an AI algorithm is used to blur these. Third, geodata is used to assign the data to a unique location and thus make it available for further use. The software Kappazunder currently has about 2000 users in the City Administration. Since the main documentation was written in 2018, there were lots of technological advancements and easier availability of those. The city administration has realized the future value of AI and works on future applications, which will be elaborated in the interview section.

4.3 Interviews

In total, five interviews were conducted for this study. The job positions, the timeframe, and additional information can be found in the methodology section in Table 5. It is important to say that the interviews were conducted in German, and the author of this study translated these into English. Therefore, some translations may be imprecise or might slightly distort the opinion of the interviewee. This needs to be considered while reading the results of the interviews. All interviewees have read their contribution to this thesis and agreed to publish it. This subchapter uses the analysis that was explained in the methodology section. Subsequently, the interviews will be analyzed according to the stakeholder group which will be the beneficiary. It will start with public administration and end with citizens. Within these stakeholder groups, the focus lies on when the benefit will occur. These time dimensions are initial-use, intermediate-use, and long-term-use. The interviewees occasionally did not specify a precise time aspect; therefore, it was not possible to determine the correct time frame. This was only the case in distinguishing between intermediate and long-term use. If this was the case, it is assigned to long-term. The following interviews describe, on the one hand, the enhanced internal and external services and, on the other hand, the benefits and potential benefits for the stakeholders. The results are reported and sorted by stakeholder groups. It was seen as the best way to ensure that the contents of the interviewees were not mixed in this part (due to approval reasons). It might seem like it the contents are reported person per person, but in fact, it is sorted by stakeholder and time and then by person.

4.3.1 Public Administration

The geodata expert Lothar Eysn was referring to the initial use of the data gathered by the mobile mapping campaign and usage by the Kappazunder software as following:

> *"At that time, it was recognized quite quickly that these data recordings with imaging sensors can be a very good input to optimize processes or even make new processes possible at all. Not only physical but also virtually."*

The author of the thesis asked if they were aware of the full potential of the gathered data and its processing when they introduced Kappazunder or if they just realized its full potential while using it. The answer was that it is a combination of both and that at the beginning, they knew that it would increase efficiency, but in the course of the project, they realized that there might be many, many more possibilities than they had thought at the beginning.

The first initial benefit mentioned, which is applicable for all users of the software Kappazunder, is the increased efficiency through digital site inspections and the optimization of administrative processes. The two pilot projects, which were already described in the documentation section, were also mentioned in the interview with Mr Eysn. The impact of these projects was that the data quality was increased for both municipal departments, and the first project has also generated additional income for the City of Vienna.

Matthias Griessenberger, the program manager of “Wien gibt Raum” was asked to explain the initial idea for the program. The software Kappazunder makes it possible to measure space virtually rather than going there physically. One detail was that the responsibilities were organized easier and that the semi-automatic logging no longer requires manual typing for applications from the office clerks. This rather happens by the one-stop-shop, which communicates with internal information systems such as a filing system (ELAK) or specialized systems (FIS) and billing systems. This increases the speed of clearing bills or official procedures. The quality of the applications will be substantially higher, as there is only one place where the customers need to submit them.

As Matthias Griessenberger was asked for the vision for the program, he answered:

“We want to use public space together and more fairly. That's our major slogan, but also rethink and adapt the processes in the wake of digitization.”

Christian Habernig, the head of IT-Innovation, was initially not involved in the project but joined at a later stage. He describes the next short-term goal for this year as:

“So, the next short-term goal would be - this is completely new - we want to draw comparisons from the two mobile mapping campaigns (2017/2018 and 2020). We want to perceive the changes in the city automatically. And that's pretty unique. If we can do that with the Kappazunder data citywide. That's something that you can't do manually anymore.”

Mr Habernig was referring to the initial use of the program as an immense simplification and acceleration of various tasks. He emphasizes that in 2017 nobody thought about letting an AI process the data to extract image data. The program was always focused on the human who uses Kappazunder to do a digital inspection. But this has changed as the City began to learn about AI and its potential.

Mr Summer is a senior expert for Smart Cities in an organization that consults the City of Vienna in this matter. He was not involved in the project "Wien gibt Raum" but has a lot of experience in the Smart City sector and a long-term outlook for digitalization in Vienna. He refers to the project "Wien gibt Raum" as a best practice example for successful digitalization and innovation in the public sector. He emphasizes that data-driven decision-making is one of the key benefits for politics and public administration. For the project, he thinks that the main benefits are increased efficiencies but also cost efficiencies and higher quality of data.

Sandra Heissenberger, who is the CISO of Vienna, was not involved in the "Wien gibt Raum" project initially, but as she is also responsible for AI, she stated the main goal of the program as following:

> *"The main goal was to create new applications and services for the administration itself as well as for citizens and the economy, which are related to the public space and the objects in the public space.*
>
> *A very clear goal at the beginning was to speed up, so to say, automate, the approval of street cafes as a service of the city.*
>
> *Employees can use Kappazunder to measure the exact space where the street café is located and then use this data to prescribe the corresponding fees without having to go on-site and measure it.*
>
> *But what benefits it will bring in the long term. That remains to be seen."*

Mrs Heissenbergers last sentence leads to the benefits for the public administration, which can be expected through the usage of the new cumulative data, so to say the intermediate-use.

She explains that analysts say that AI is one of the most important drivers for digital transformations. Therefore, in the next years, it will get much attention – it could help to make processes more efficient. For example, to process and analyze a large amount of unstructured data. Without technology, humans would not be able to process that data and draw meaningful conclusions. The data produced by the mobile mapping campaign can further be used with AI to evaluate the overall road condition or find street damages.

Mr Eysn also mentioned that during the realization of the project, they came up with the idea to use AI to analyze the road conditions. Another idea was to teach the AI to detect street signs and the additional signs (for example, the additional signs at one-way signs with the addition: excluding cyclists). He also mentions that when using AI with that data, more use cases will evolve and even some cases that could not be solved before because the data was previously not existing. Efficiency increases, better planning, and improvements of manual processes are some benefits that were mentioned in the intermediate use timeframe.

He emphasizes that from the view of a surveying department, high-quality geodata are crucial. An upcoming trend is Geo AI; this will need high-quality input data. Geo AI has many potentials and can bring a surge in utilization possibilities.

Mr Habernig indicates that one of the main benefits is the completeness of data for the whole city. Through the implementation of automation with AI, it is possible to provide statements to objects area-wide. As an intermediate to long-term goal, he sees the benefits provided from the comparison of multiple mobile mapping campaigns. Furthermore, he explains how the connection of the different surveying methods can be beneficial. Combining data that was gathered by the mobile mapping campaign, the yearly "Orthofoto" (aerial photograph), and oblique images could give new perspectives and information to specific objects in the public space. These objects could be street signs, pedestrian walks, ground markings, traffic lights, facades, roofs, or even moving objects such as cars.

As the number of campaigns rises, more automated conclusions can be drawn from the different campaigns. This leads to a better assessment of the changes in the city and the development of the city in an overall view. A long-term goal would be to shorten the intervals of the campaign, which are at the moment at one campaign every 2 or 3 years. A further long-term perspective (very long future) would be to move to real-time and near-time data sources. There is no planning so far; this is just a vision. For example, to gather data from buses in real-time and incorporate that into Kappazunder.

Mrs Heissenberger says that new innovative services for the public administration itself are very important to get more efficient on the intermediate and long-term view. She has a similar opinion as Mr Habernig on the comparison of the data gathered by multiple mobile mapping campaigns and explains it with a potential use case. As mentioned, one use case for AI applications could be the detection of street damages. The next step is the comparison of road conditions from different campaigns, so to say the comparison of the campaign from 2017/2018 and 2020. With further campaigns in the future, an additional step is the prediction of bad road conditions at a certain date with a certain probability according to the previous data gathered by these mobile mapping campaigns over some specific time frame.

She also mentions that further usages in the intermediate or long term could be the automated detection of parking spaces in the public space. These usages are AI processed detection of traffic lights, number of floors of buildings, window areas, pedestrian crosswalks, or other objects which are in the public space.

Mr Eysn highlights the importance of complete historical data as one of the long-term benefits for the public administration. Complete historical image data is highly relevant for preserving evidence also from a legal point of view. It is also relevant for the future, as the employees can look back in some years to see how Vienna has changed. This will potentially have added historical value, which can not be assessed yet. He is also convinced that AI will have much impact in comparing these datasets from different years – as these datasets are huge - it is impractical for humans to go through them manually. Furthermore, it was said that the gathered data builds the foundation for further optimization of processes.

Mr Summer thinks that in the long-term, process monitoring and data-driven decision-making are some main goals. Further goals are the resolution of long-term conflicting goals for achieving climate protection goals. Achieving true smart sustainability in the economic, environmental, and social sense is crucial. He mentions that the data provided by the public administration (IoT data and AI-supported analysis) can help to make decision making on many levels. For example, on a political level, an analysis of this data can help to facilitate evidence-based, democratic, or non-democratic decision-making.

4.3.2 Enterprises

Mr Griessenberger indicates that some explicit benefits for enterprises are that information is easier to reach and has a better quality. Furthermore, there is no need to go to a municipal department or several municipal departments physically. Everything is in one place – the One-Stop-Shop. But it will still be possible to go to the municipal department offices and do it offline. However, it will be managed in the new backend-System. Additionally, enterprises are not bound to any opening times – so they can submit the application whenever they want. The application in the One-Stop-Shop has better guidances than the previous application procedures, so it is less likely for enterprises to unintentionally delaying the procedure by not submitting mandatory documents. There is one point of contact with the public administration; the whole information is compactly combined here. To sum up, the main benefits are faster and better information, shorter processing time, and more convenience. This is also applicable for citizens, but the target group for the "Wien gibt Raum" are enterprises and associations for now.

Lothar Eysn mentioned that they already received requests from enterprises to get this sort of data. He described one request which was from a company whose main task is to carry out heavy transports. So far, they planned and measured the route manually, with access to the data from the mobile mapping campaign a digital route planning would be possible. That can be seen as a potential benefit for enterprises in the future.

Christian Habernig explains that one objective is that the data gathered by the mobile mapping campaign should be freely available in the Open Government Database (OGD). This can be highly beneficial for enterprises as they could create a business model which uses this input data to create tools and applications. He already gave examples of how enterprises could use the data. This will most likely affect the logistics or mobility aspects of enterprises as it makes it possible for enterprises to inspect locations virtually. One example could be route planning for heavy transports or to find short-time stop opportunities, or to get an overview of parking options in the desired area.

Sandra Heissenberger defines the benefits from the project “Wien gibt Raum” for enterprises as an end-to-end digitalization. They can sign up digitally and do not need to bring a plan to the municipality. Within the public administration, it is faster distributed internally, so a permit and a fee regulation are made fully electronically. This saves the company and the authorities much time.

She has also emphasized that publishing the mobile mapping campaign data as Open Data will benefit the economy in various ways. Vienna is already publishing many data in its Open Government Database, it is a proven way to create value for various stakeholders. She is convinced that publishing this data will be extremely beneficial because enterprises could create applications that could link all kinds of other data objects. This will bring forth a high number of new applications and benefits the economy, its citizens, or the public administration itself.

Mr Summer has a similar opinion and likewise said that putting this data as OGD is very important and will potentially generate immense added value for the regional economy, which is also focused on companies in the mobility sector. Furthermore, he thinks this is a huge opportunity to be innovative.

4.3.3 Citizens

Christian Habernig has a very good explanation why citizens might not directly benefit from the mobile mapping campaign, Kappazunder or publishing of the data:

> *“The citizens mainly benefit from a well-managed city. The benefits for citizens are that the rules of the city continue to be respected by those who make changes in the cityscape. Therefore, it is important to inspect exactly that and this takes time and effort. When these functions can be done digitally, it saves the administration time and leads generally to faster procedures. This is the main aspect from which citizens can benefit.”*

He also mentions that it increases the quality of services for the citizens. On the one hand, because it is more efficient and on the other because it is faster. Furthermore, the increased quality will also have a positive impact.

Sandra Heissenberger explains that one of the goals of "Wien gibt Raum" or digitalization, in general, is to take services online and minimize physical contact in the office. Making the services digital benefits the customers as it is more convenient and less time-consuming to use Vienna's services. A long-term benefit could be provided by digitalization and AI when citizens are provided with the right things according to their situation in life. For example, proactively provide services from birth to the first spot in a public kindergarten or public school.

Nikolaus Summer thinks that the availability of the data for citizens could be a huge opportunity for them. As they can make elucidated decisions, from consumption decisions to political participation. Furthermore, citizens can benefit from a higher level of comfort and higher sustainability.

4.3.4 Conclusion

As in most interviews, research institutes were also mentioned at some point, they also need to be considered for this thesis. The interviewees had research institutes mainly in mind while talking about publishing the data as Open Government Data. Nikolaus Summer said:

> *"There is, of course, enormous potential for a new scientific revolution if the data is available in a good quality and also searchable, analyzable and processable as such. Just as the invention of printing contributed to the spread of knowledge and thus to the subsequent scientifical revolution. That is very optimistic, we may also be drowning in the huge amount of poor quality data."*

At the end of the interviews, all interviewees were asked to briefly explain their top three benefits from either the use case "Wien gibt Raum" or the usage of that data in the future. The author tried to conclude this in a very short and clear form which can be seen in Table 6.

Number	Interviewee	Job title	Benefit 1	Benefit 2	Benefit 3
1	Lothar Eysn	Co-Head of the Department & Head of Innovation in IT	Efficiency increase	Historically complete data (as evidence)	Surveying aspects, such as the quality of geodata.
2	Matthias Griessenberger	Program Manager “Wien gibt Raum”	Data quality	Productivity increase	Harmonization of processes and workflows
3	Christian Habernig	Head of IT Innovation	Data completeness	Publishing the data into Open government Database (big enabler)	Data-driven decision making (for city development and city planning)
4	Sandra Heissenberger	Chief executive security officer	High accuracy for forecasts	Utilize AI where it outperforms human performance (e.g., image classification)	Time savings and the possibility to process large amounts of data
5	Nikolaus Summer	Senior Expert Smart City Agency	Data-driven decision making and process monitoring	Creating opportunities, social inclusion and participation	Make a large amount of information cognitively usable and thereby remain sovereign over the data

Table 6: Top three benefits

5 DISCUSSION

This chapter consists of three sections. First, the results will elaborate on the most relevant findings of the interviews with the usage of the adapted benefit framework (from Table 4). Secondly, the limitations of this thesis will be presented. Lastly, recommendations for further research are given.

5.1 Results

In this section, the findings of the chapter “Case City of Vienna” will be compared with the underlying academic literature so that the research question “How can municipalities benefit by using IoT and AI with geodata to enhance their services?“ can be answered. Therefore, the adapted benefit framework will be filled with the results of the interviews and the documentation. Table 7 shows the most relevant benefits in a short and precise way. The table also links the benefits with the underlying benefit evaluation. Also, a compact interpretation is given and compared to previous literature. This interpretation will also show which major benefits could have been expected based on prior literature but did not show up. It will also show benefits that were not mentioned in previous literature.

Stake-holder	Benefits	Benefit evaluation	Time/ use
Public administration	Reorganized processes (optimization)	Organizational benefits, IT Infrastructure – support organizational changes	Initial use
	Simplification of tasks	Organizational benefits, Operational – productivity improvement	
	Better networking for municipal departments	Individual benefits, not defined	
	Complete overview of objects in the public space	Information Quality, Completeness	
	Generated additional income	Organizational benefits, Managerial – Better resource management	
	Improved data quality	System Quality, Data accuracy	
	More efficient field services (digital site inspection)	Organizational benefits,	
	Increases efficiency in clearing bills or official procedures	Organizational benefits, Operational – productivity improvement	
	Applications have higher quality	Information quality, Accuracy	
	Cost efficiency	Organizational benefits, Operational - Cost reduction	

Public administration	Acceleration of tasks	Organizational benefits, Operational – productivity improvements	Intermediate use
	Make processes more efficient	Organizational benefits, Operational – productivity improvements	
	Automated detection of objects	System quality, Usefulness of system features and functions	
	Better planning	Organizational benefits, Managerial – Improved decision making and planning	
	Improvements of manual processes	Organizational benefits, IT Infrastructure – support organizational changes	
	Higher quality of data	Information Quality, Accuracy	
	Completeness of data	Information Quality, Completeness	
	Automated conclusions	Organizational benefits, Managerial – Improved decision making and planning	
	Complete historical data	Information Quality, Completeness	Long-term use
	Preserve evidence (for legal implications)	Not defined	
	Evidence-based decision making	Organizational benefits, Managerial – Improved decision making and planning	

Enterprises	Easier use of public space	Organizational benefits, Operational - Productivity improvement	Initial use
	Single point of contact	Organizational benefits, Operational - Productivity improvement	
	Information is combined, has better quality and is easier to reach	Organizational benefits, Operational - Productivity improvement	
	Everything is available digital	Organizational benefits, Operational - Productivity improvement	
	Not bound to opening times	Organizational benefits, Operational - Productivity improvement	
	Better guidance in the application	Organizational benefits, Operational - Productivity improvement	
	Shorter processing time	Organizational benefits, Operational - Productivity improvement	
	Increased quality of services	Organizational benefits, Operational - Productivity improvement	
	Access to high-quality geodata	Organizational benefits, Strategic – build business innovation	Intermediate use & long-term use
	Possibility to create applications with the OGD	Organizational benefits, Strategic – support business growth	
	Possibility to be innovative with the OGD	Organizational benefits, Strategic – build business innovation	

Citizens	Easier use of public space,	Individual benefits, Time savings	Initial use
	Single point of contact	Individual benefits, Time savings	
	Information is combined and has better quality, and is easier to reach	Individual benefits, Better accessible	
	Everything is digital available	Individual benefits, Better accessible	
	Not bound to opening times	Individual benefits, Better accessible and time savings	
	Better guidance in the application	Individual benefits, Better accessible and time savings	
	Shorter processing time	Individual benefits, Time savings	
	Increased quality of services	Individual benefits, Higher quality of life	
	Benefits by applications from enterprises using OGD	Individual benefits, not defined	Intermediate & Long-term use
	Shorter processing time	Individual benefits, Time savings	
	Elucidated decision making	Individual benefits, Improved decision making and planning	

Table 7: Results of Case in Adapted Benefit Framework

As shown in Table 7, a wide range of benefits were found or expected to occur in the future. Benefits that could have been expected beforehand but were not reported in the documentation or during the interviewees were benefits in the categories "Information Use", "User satisfaction", "Service Quality" or in the Organizational benefits in the dimensions "Strategic" and "IT Infrastructure". Expected benefits without regard to the mentioned categories could have been empowerment, support business alliances, amount of use, frequency of access, overall satisfaction or the regularity of use. The benefits mentioned in the case but not stated in the literature before were the preservation of evidence (for legal implications) and better networking for municipal departments, which was further classified as an individual benefit. Also, all other induvial impacts were not clarified in prior literature. The author decided to categorize them as
time savings, better access, higher quality of life, improved decision making and planning or not defined. It is not clear how to correctly classify the not defined benefits, as it depends heavily on which applications can be produced with the usage of the OGD, therefore, it was decided to call it not defined.

In order to answer the research question "How can municipalities benefit by using IoT, AI and Geodata to enhance their services", it is essential to mention that the citizens and enterprises most of the time do not benefit directly from the implementations of these technologies.

Citizens and enterprises benefit indirectly from the improvements of internal services, processes, and higher quality and complete data; they benefit when a municipality tries to make a city smarter. The benefits of the public administration by applying these technologies are efficiency increases, higher data quality, data completeness, higher accuracies for forecasts, data-driven decision making, harmonized processes and time savings deduced from those. Citizens and enterprises mainly benefit from a better-managed city and enhanced services. This leads to time savings while interacting with authorities (processing, waiting and travel time), the possibility to have one point of contact only and organize everything digitally. One example given in the case was that when Artificial Intelligence is used to detect the road condition, more efficient road network maintenance is possible. This increases the efficiency within the public administration, and it allows to react faster to changing circumstances. As a result, citizens and enterprises benefit from a better-maintained road network, contributing to a higher quality of life.

5.2 Limitation

As most studies have some limitations due to various reasons, this study also has limitations that will be introduced after that. One limitation is the lack of academic literature on the specifics of this thesis, which led to the creation of the adapted benefit framework. However, most limitations are due to the brief timeframe of less than four-month to finish the thesis, this did not allow a more comprehensive approach of data gathering. This leads to a considerably low number of interviews; five interviews are not enough to generate valid generic statements. The interviews also miss some important groups of people, like users or developers of the software. Furthermore, citizens or enterprises were not asked for their opinion. A large-scale survey of affected individuals could provide more insights into the benefits that occurred, which could also be measured. This leads to another limitation: to fully exploit the adapted benefit framework, many interviewees and participants in surveys are needed. A quantitative analysis of data such as decreased time per work order, productivity increase or cost savings could give additional insight, but this was impossible due to the lack of data. A further limitation is that the explained program “Wien gibt Raum” is still a work in progress. This results, on the one hand, in a lack of useable data. On the other hand, that most of the benefits are expected benefits. It is not yet clear if they will occur in the same way as the interviewees expected them. One limitation is the fact that this study is a single case study; comparing similar cases will bring more generalizable results. With that said, this thesis cannot be taken as generalizable as other municipalities might have different tasks which are derived from their respective jurisprudence. Furthermore, it needs to be said that these are expected benefits as it heavily depends on the “smartness” of citizens and enterprises to take advantage of digital services. This might differ considerably from city to city and country to country, depending on how digitally represented the citizens and enterprises.

5.3 Further research:

Further research has to be done regarding the academic concepts to analyze the benefits of information systems for municipalities or the government sector as a whole. The adapted benefit framework works decent for this thesis, but it can certainly be more specific and, for example, have more diversified stakeholder groups. As smart cities and the mentioned technologies are relatively new, the impact of those for the municipalities have to be evaluated in a further academic study.

Future studies with a similar structure should include a higher number of interviews and surveys of affected persons such as users within the government or citizens and enterprises. A future study on this specific case should be conducted in four or more years as the AI framework would already be in use, and more mobile mapping campaigns would have been conducted. Furthermore, the citizens and enterprises would have time to use the new applications and evaluate their benefits. With these conditions, a more thorough data gathering would be possible.

6 CONCLUSION

This paper has tried to show how the different groups of stakeholders, public administration, enterprises and citizens can benefit by the usage of IoT, AI and geodata to enhance municipality services. The benefits were evaluated with an adapted benefit framework that consists of multiple different benefit frameworks from prior literature. The adapted benefit framework uses different classifications to evaluate the benefit for the different groups of stakeholders. Furthermore, it shows a timeframe when the benefit occurred or will occur – this was done with the dimensions initial use, intermediate use and long-term use. A case study research of the City of Vienna was done. Vienna's goal is to become the digital capital of Europe. They have a comprehensive range of publicly available strategy papers that aim to promote digitalization and make Vienna a smarter city. The answer to the research question "**How can municipalities benefit by using IoT and AI with geodata to enhance their services?**" is based on interview results, strategy papers and documentation of the program "Wien gibt Raum". Vienna was chosen as a case because they promote innovation and have a pioneering role in many fields regarding digitalization in Europe.

The central answers to the research question could be expected, the major benefits are productivity and efficiency increase within the public administration. Moreover, a higher quality of data and more complete data can be achieved, allowing data-driven decision-making and better forecasts. The case study has shown many potential use cases and that using these technologies is only just the beginning. An unusual benefit that was found was the preservation of evidence for legal implications and better networking within the public administration. A further benefit, which was not to be expected in a governmental organization, was creating new income streams through the usage of the gathered data. Enterprises can benefit in various ways when the gathered data is published in an open government database. This also can benefit citizens from new and innovative applications with these gathered data as input data. It was found that citizens and enterprises do not directly benefit from the usage of these technologies. However, they benefit indirectly from a better-managed city and time savings while dealing with authorities. Also, better and easier access to governmental services, which also provide more comprehensive information, is a major benefit for both stakeholder groups.

This thesis has clearly shown that all stakeholder groups can benefit when using technology to enhance the services of a municipality. The paper can be seen as a study of a real-world example of using the combination of these technologies in a municipality context and an analysis of the benefits which result from those.

Based on the learnings from this study, further recommendations for the City of Vienna or other municipalities that have similar cases can be given. It is recommended to evaluate and measure benefits for all stakeholder groups to see if new IT systems were successful. An evaluation for users' satisfaction could be a survey, which reveals the satisfaction from the users of the new IT system and its implications. A further evaluation can be done with a cost/benefit analysis as this case does not include any cost savings; it was not possible to analyze any cost-related areas. It is further seen as necessary that the expected benefits should be compared to the realized benefits to see if implementing an IT system was successful. This is seen as very important to get further support for implementing innovative solutions. As long as the implementation creates benefits for one or more stakeholder groups while not reducing them for others, it has a net benefit that can be considered successful.

It needs to be mentioned that the results of this thesis do not reflect the official views of the City of Vienna, just those of the author.

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APPENDICES

Interview Guideline German

Wie können die Technologien KI, IoT und Geodaten helfen Services der Stadt Wien zu verbessern? Was ist der Nutzen/Benefit der verschiedenen Stakeholder-Gruppen (Öffentliche Verwaltung, Bürger, Unternehmen). In Wien wäre ein konkreter Fall die Straßenbefahrung und in weiterer Folge die Nutzung dieser Daten, die Anwendung Kappazunder und generell das Programm “Wien gibt Raum”.

Frage Nr.	Themenfeld	Frage
1	**Einleitung**	Was ist Ihre aktuelle Jobposition (auf Englisch)? Wie lange arbeiten Sie schon in dem Bereich? Waren Sie in dem Projekt „Wien gibt Raum oder der Befahrung oder der Software Kappazunder involviert? • Falls Ja: Was war Ihre Rolle? • Falls Nein: Inwiefern sind Sie involviert, wenn es um die Nutzung der folgenden Technologien geht? (KI, IoT & Geodata)

2	**Zielsetzung**	Was war das Hauptziel des Projektes? • Wurde der Nutzen in der Anfangsphase definiert? • Wurden die Nutzen in anfängliche, zwischenzeitliche und langfristige Nutzen unterteilt? • Wurde der Nutzen für die verschiedenen Stakeholder Gruppen definiert? (Stadtverwaltung, Bürger, Unternehmen) Was ist das Hauptziel in der Nutzung dieser Technologien? • Wurde der Nutzen in der Anfangsphase definiert? • Wurden die Nutzen in anfängliche, zwischenzeitliche und langfristige Nutzen unterteilt? • Wurde der Nutzen für die verschiedenen Stakeholder Gruppen definiert? (Stakeholder Gruppen: Stadtverwaltung, Bürger, Unternehmen)
3	Prozesse	Hat sich der definierte Nutzen während der Realisierung des Projekts geändert? Haben sich die definierten Nutzen während der Realisierung der Technologien verändert?

4	Bewertung	Haben Sie eine Art von Messung integriert, um den Nutzen zu bewerten?
5	**Nutzen/ Benefits**	Was sind die Nutzen, welche durch das Projekt enstanden sind oder entstehen werden/könnten? • anfängliche, zwischenzeitliche und langfristige Nutzen unterteilt? • Stakeholder Gruppen: Stadtverwaltung, Bürger, Unternehmen Was sind die Nutzen, welche durch die Anwendung dieser Technologien enstanden sind oder entstehen werden/könnten? • anfängliche, zwischenzeitliche und langfristige Nutzen unterteilt? • Stakeholder Gruppen: Stadtverwaltung, Bürger, Unternehmen
6	Analyse	Wird/Wurde der Projekterfolg gemessen? • Falls ja, wie? • Gibt es KPIs (Key Performance Indicators)? Wird der Erfolg des Einsatzes dieser Technologien gemessen? • Falls ja, wie?

		• Gibt es KPIs (Key Performance Indicators)?
7	**Strategisch**	Was ist die strategische Langzeitvision für den Einsatz dieses Projekts? Was ist die strategische Langzeitvision für den Einsatz dieser Technologie?
8	Kritisch	Gab es negative Auswirkungen für eine der Stakeholder-Gruppen?
9	**Zusammenfassend**	Was sind Ihrer Meinung nach die 3 wichtigsten Vorteile des Projektes/ der Nutzung dieser Technologien?
10	Zusätzliche Informationen	Möchten Sie noch etwas hinzufügen, was zu diesem Thema noch nicht besprochen wurde?

Interview Guideline English

How can the technologies AI, IoT and Geodata help to enhance services? How does this benefit the different stakeholders. In the Case of Vienna and more specific with the Mobile Mapping and usage of the data, the application Kappazunder (internal software) and the program Vienna provides space.

Question Nr.	Topic	Question
1	Introduction	What is your current job title/position? How many years have you been working in this field? Have you been involved in the project „Wien gibt Raum? (or the sub projects Kappazunder or Mobile Mapping and its data usage)“ • If yes: What was your role? • If no: Are you involved in the technologies AI, IoT and gedata?
2	Goal	What was the main goal of this project? • Were the benefits defined in the initial stage? • Did you divide the benefits in initial, intermediate and long term use? • Did you define the benefits for different stakeholder groups?

		What is the goal of using these technologies? • Were the benefits defined in the initial stage? • Did you divide the benefits in initial, intermediate and long term use? • Did you define the benefits for different stakeholder groups?
3	Process	Have the benefits defined changed during the realization of the project? Have the benefits defined changed during the realization of the technologies?
4	Measurements	Did you integrate some kind of measurement to rate the benefits?
5	Benefits	Can you tell me all the benefits you see in the project? • Initial, Intermediate or long term use • Enterprises, Public administratioh, citizen
6	Analysis	Is the project sucess measured? • If yes, how? • Are there key indicators? If the sucess of using these technologies measured? • If yes, how?

		• Are there key indicators?
7	Strategic	What is the strategic long term vision for using this project? What is the strategic long term vision for using this technology?
8	Critical	Have there been any negative implications for any stakeholder?
9	Summary	What do you think are the three most important benefits from this project/ these technologies?
10	Additional Information	Do you like to add anything that have not yet been discussed for this topic?