Mundher Al-Janabi

GEOAI AND CLOUD TECHNOLOGY IN KERAVA MUNICIPALITY

Thesis
CENTRIA UNIVERSITY OF APPLIED SCIENCES
Master's degree
May 2024

centria
University of Applied Sciences

ABSTRACT

Centria University of Applied Sciences	**Date** May 2024	**Author** Mundher Al-Janabi
Degree programme Master of Engineering, Information Technology, Cloud-Based Software Engineering		
Name of thesis GEOAI AND CLOUD TECHNOLOGY IN KERAVA MUNICIPALITY		
Centria supervisor Dr.Aliasghar Khavasi		**Pages 6+75**
Instructor representing commissioning institution or company Tuija Aaltonen		

This thesis examines how the municipality of Kerava, Finland, integrates geographic information systems (GIS) and artificial intelligence (AI) through cloud technologies to improve pipeline management systems. The application of three-dimensional (3D) modelling and GeoAI systems is a significant focus. Implementing these integrations is necessary to improve control of water supply and sewerage systems and the entire infrastructure. This study explores how, using cloud systems, AI and GIS, working together, can create accurate 3D models to simplify the management and maintenance of pipeline networks in the Kerava municipality. The study began with a general overview of various technologies in GIS and AI. The pros and cons of this integration with cloud systems were discussed in detail. The GIS system is the main tool for managing pipeline information in Kerava. This data includes topographic maps and satellite images. However, this integration facilitates clear visualization of the condition, type and location of the pipeline AI, by automating the process, improves this system, greatly increasing the accuracy and efficiency of various pipeline monitoring and management operations. This is necessary for effective resource management, as well as reducing risks such as accidents. The thesis also described the scalability and reliability that is achieved using cloud computing that supports extensive data processing. This is essential for efficient pipeline management.

The results show that GIS, AI and cloud technologies are simplifying the modelling process, providing improved accessibility of various piping systems. This integration has the potential to change infrastructure management to a more reliable one, using advanced technologies for the sustainable development of the Kerava municipality.

Key words: Cloud Technology, CAD, GIS, IoT, LiDAR, Machine Learning, QGIS, Urban Water Systems, Water Resources Managment

CONCEPT DEFINITIONS

3D: Three Dimensional

API: Application Programming Interface

CAD: Computer-Aided Design

CNN: Convolutional Neural Network

DL: Deep Learning

EC2: Elastic Compute Cloud

GB: Giga Byte

GeoAI: Geospatial Artificial Intelligence

GPS: Global Positioning System

IoT: Internet of Things

LiDAR: Light Detection and Ranging

MB: MegaByte

ML: Machine Learning

MLaaS: Machine Learning as a Service

PM: Predictive Maintenance

QGIS: Quantum Geographic Information System

RNN: Recurrent Neural Network

SSAS: SQL Server Analysis Services

TB: Tera Byte

UWS: Urban Water Systems

VR: Virtual Reality

VGI: Volunteered for Geographic Information

WRM: Water Resources Management

WWM: Wastewater Management

FIGURES

INTRODUCTION

In the age of modern urbanization, municipalities like Kerava face a mounting problem of sufficient water and sewage system management. The new era, which involves intricacy, inequity, and high maintenance costs, also demands the development of better data management techniques than the current two-dimensional data management solutions, which are very efficient. This implies that there is a significant improvement which is very detailed as well as accurate model of water and sewerage network in Kerava.

With this multi-faceted approach, in particular, the municipality will enjoy its many advantages which include, but are not limited to, better usage of resources, additional efficient operations and better decision-making power Therrien et al. (2020). Besides, a 3D model helps make a comprehensive visualization of the various infrastructure parts which enables advanced maintenance and early intervention that cuts failures. This idea is garnered from the conviction that the regimes for managing water and sewage networks in Kerava should be redeveloped to include a new technological outlook and a creative approach. The goal is to build a system which will be robust and flexible as well as equipped with advanced data analytics, electronic cloud computing, and software tools specially designed for urban infrastructure management. Such a framework will not only cope with the present problems but also ward off committed mistakes and provide recommendation to avoid further ones. Sustainability is thus one of the goals of the city, and this project also means treating the citizens of a better city.

Today, great changes are taking place in the field of digital technologies, and achievements in development are difficult to ignore. One of the reasons for this rapid growth is the rapidly evolving urban landscape. Thanks to the combination of Geographic Information Systems (GIS), artificial intelligence (AI) and cloud computing, an effective and innovative direction like GeoAI has emerged. Its huge advantage is the great opportunities that have changed and improved the usual management of municipalities and urban planning. The municipality of Kerava, where the author of the thesis also works, is in a dynamic metropolitan area in Finland. This thesis explores how to use GeoAI and cloud technologies to improve the operation of pipelines by integrating 3D modeling, improving the efficiency of spatial data management in the municipality of Kerava.

Around the world, urban centres face rapidly increasing infrastructure management challenges. Kerava strives to use the latest technology to solve such problems. Facilitated by cloud computing, integrating GIS and AI helps find the best solution, thereby enabling increasingly sophisticated data analysis and management options.

GeoAI is a revolution in urban planning and management. AI is capable of optimizing planning for the sustainability of land use, public transport routes, as well as changing and many times improving various strategies that are capable of responding to emergency situations. The application of GeoAI in the municipality of Kerava will be able to change the way the municipality interacts with its geographical environment, considering the needs of residents, changing the solutions used in urban planning. For depth of data interpretation, 3D GeoAI pipeline capabilities are important as they provide 3D visualizations and analyses, enabling more accurate urban project planning.

Despite its advantages, the implementation of GeoAI in data management and technology integration faces various challenges. Data privacy and security are of paramount importance. GeoAI systems process critical and sensitive information, and the computational requirements to run advanced AI algorithms require expensive and complex IT infrastructures to manage. Broader use of GeoAI in municipal settings is facilitated by cloud technologies as they introduce enhanced data security measures as well as scalable resources.

In GeoAI deployment, cloud computing plays a major role. They provide all the necessary infrastructure that can support extensive data processing and, of course, storage. The introduction of cloud technologies in the Kerava municipality will facilitate access to innovative computing resources that do not require capital investments.

Cloud platforms can offer flexible data management and various computing tasks to handle the changing dynamics of urban data. Cloud technologies provide a centralised platform for analyzing and distributing data, improving cooperation in unrelated industries and stakeholders.

The main focus of this thesis is to study how cloud technologies are contributing to improving pipelines using GeoAI in the municipality of Kerava, including various 3D modeling capabilities.

The project aims to showcase the current state of GeoAI technologies and their application in urban planning. It also seeks to analyze the challenges and advantages of integrating GeoAI cloud systems in municipalities. An important objective is to propose the implementation of a 3D GeoAI pipeline in Kerava, enabling efficient management and analysis of spatial data. Ultimately, the project aims to demonstrate the benefits of an advanced 3D pipeline based on GeoAI technologies.

The integration of GeoAI and cloud technologies in urban planning and management presents an innovative opportunity for the Kerava Municipality. This thesis explores the technical and operational challenges associated with these technologies, offering practical implications and strategic frameworks to enhance residents' quality of life and contribute to sustainable city development. By utilizing a pipeline enhanced with GeoAI, supported by cloud technologies, and enriched with 3D capabilities and spatial data, the municipality can establish the most recent urban governance and interaction benchmarks.

2 . BACKGROUND

Infrastructure data administration includes a complex number of issues, especially in cities such as Kerava. The spread of data between databases, data tables and repositories creates a major challenge. Spreading data requires efficient data gathering, merging, and information management. On the other hand, the multiplicity of data formats from various sources is another barrier in the process of data gathering and analysis, therefore discouraging faster data integration and effective collaboration among stakeholders. One more challenging task is to bring together the disparate parts of data sources. Many plans face obstacles in the process of unearthing coherent observations from diverse and heterogeneous data sources and formats. The phenomenon of fragmentation almost always leads to fragmented views, which, in turn, quite often decreases the quality of the process of decision-making Wang et al (2021).

Professional software tools, as well as the design of standardized data protocols, will be key elements of any modern urban infrastructure management strategy that seeks to tackle complexities. These tools achieve data from various sources integration, formats standardization and efficient management processes. A unified data platform may result in a state of improvement of resource allocation, service optimization, and facilitation of the decision-making process in infrastructure development for Kerava City Barton et al (2022). Simpler data practices not only improve in-house processes but also promote dialogue and information interchange among those who matter in the whole process. The existence of interoperability brings about the effective sharing of information, encourages creativity, and motivates joint ventures in pursuit of sustainable urban development. The adaptation of these technology breakthroughs underpins urban areas like Kerava's effective use of infrastructure data, thus increasing efficiency, resilience, and outcomes that are good for all residents and stakeholders.

1.1 GIS AI and 3D model of pipeline

In modern society, we are witnessing the unfolding of global digital transformation. Every day, a huge amount of increasingly complex algorithms is generated, and computational power is growing rapidly. Artificial intelligence is becoming a part of everyday reality in many fields. Machine learning is expanding horizons for business management and leading us to understand the possibilities of the Digital Society we live in today Y Du, S Zlatanova (2006).

The Digital Society is a community that utilizes information and communication technologies as tools for daily life, based on the application of microelectronics, local and global computer networks, applied software technologies, and machine algorithms. These tools gather, process, generate, and distribute information to users through global telecommunication systems. Our world today is very young; it has been created with breakthrough technologies and massive data generation over the past year or two, surpassing the entirety of history in preceding years of its existence Srivastava, (2020).

Intelligent decision-making today helps people improve the quality of life, enhance businesses, and improve the surrounding world by using data. Smart decision-making involves effective project management, strategic goal planning, defining optimal metrics, and security systems for large-scale automation. Intelligent solutions today enable the transformation of information into practical actions. Today's architecture of solutions is based on careful context formation through tools of the Digital Society and intelligent forecasting with resulting goal formulation provided by Artificial Intelligence.

Artificial intelligence is a collection of intellectual constructs (algorithms, software solutions) that are available for processing input data volumes. Artificial intelligence makes analytical decisions and builds predictive models for intelligent decision-making and management in the digital community Dawood, Elwakil, Delgado (2020).

Forecasting artificial intelligence refers to the volume of new data that users obtain due to the intellectual activity of software components. Location data is a link for automation algorithms of predictive modelling and target components of decision-making space. Location analytics provides business advantages and enables smart management and decision-making Somu (2021).

Creating a pipeline model in ArcGIS Pro involves collecting spatial data such as locations, various infrastructure, and environmental data. Data is prepared and cleaned. This ensures accuracy. Tasks include, for example, georeferencing or digitizing maps, then creating a utility network in ArcGIS Pro, with which pipelines can be modelled and manipulated, while also providing the ability to analyse connectivity and flow. To do this, one uses the tracing and network diagram's function. For valves and pipes, feature layers with important attributes, such as size or material, are specially configured. In ArcGIS Pro, analytical tools are needed to detect failures, assess risks, and of course help with maintenance planning. Visualizations and maps are needed to present pipeline data clearly and effectively. Symbols are used for this; they make the information more understandable. Integration with a system such as ERP is needed for real-time monitoring and to ensure clear interaction of the conveyor model with external platforms. The resulting model, thanks to the capabilities of

ArcGIS Pro, can be used by publishing maps and models in the form of web layers, maps, and applications as illustrated in the provided picture (Figure 1). This is all done through ArcGIS Online, or Portal for ArcGIS Li, Z.(2020).

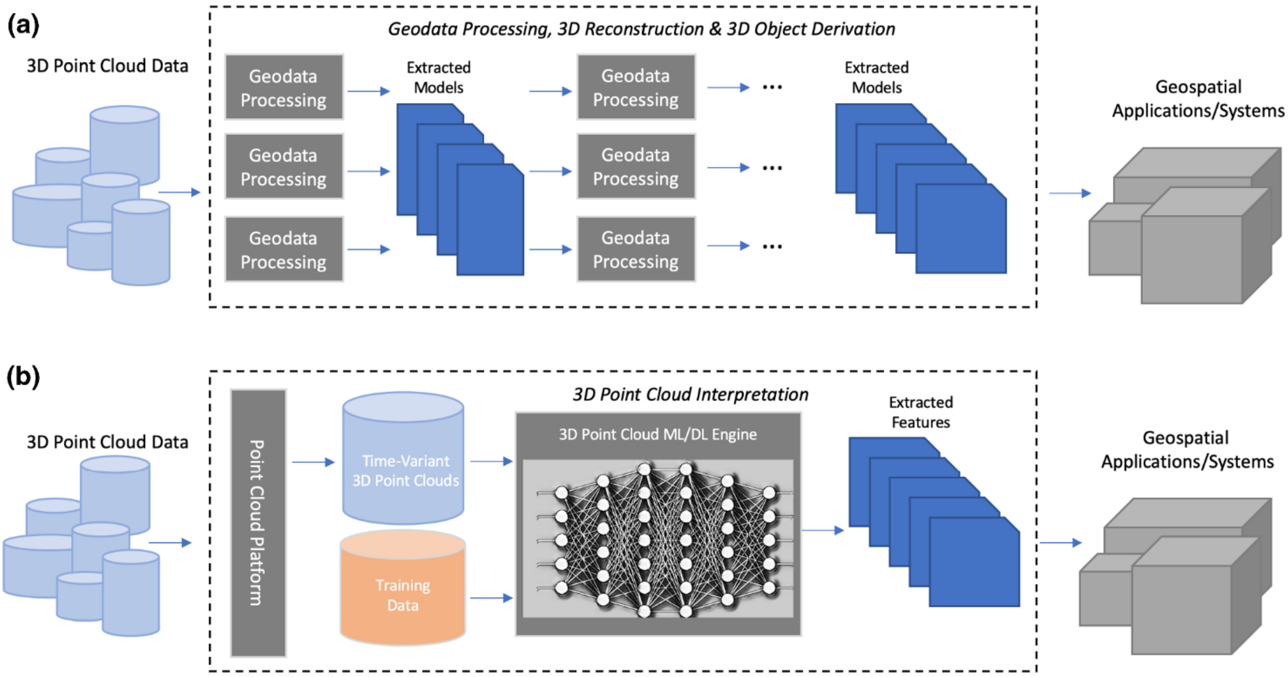

Figure 1Comparative Workflows for 3D Point Cloud Data Processing: Traditional Geodata Processing vs. ML/DL Interpretation Döllner, J. (2020)

1.2 Variations Industries With Intelligent Location Analytics and Machine Learning

Many global businesses use location analytics to reveal concealed patterns, gain insight and create competitive advantage. The advantages of intelligent location analysis can be enhanced through the quality organization of artificial intelligence modelling. Place analytics supported by machine studying promotes online breakthrough information acquisition. Place analytics provides the opportunity to obtain intelligent location forecasting Mishra, AK Tyagi (2022).

Intelligent location is location data based on geographical systems, supplemented by artificial intelligent automation and scalable online platforms. Intelligent location data helps transform entire industries. More than 90% of executives believe that location information is crucial for the success of businesses and communities. Executives, managers, and operators use intelligent location to find optimal locations when selecting trading platforms, manage assets in real-time, and maintain or repair critical infrastructure. Sun, Scanlon (2019).

Retailers in the retail sector use machine learning and location analysis to select sites, support customers, set prices, optimize supply chains, location-based advertising, and provide personalized customer service as illustrated in the provided image (Figure 2). Location analytics is the analysis of branch location properties Wang, Gopal, Shankar, Pancras (2022).

In manufacturing, intelligent location systems are used to enchase logistics, geotarget route planning, plan preventive maintenance and detect atypical actions that slow down production Wenzel, Smit, Sardesai (2019).
Government agencies use machine learning algorithms based on imagery obtained from geographically referenced drones and satellites to automatise work, model business development and assess the condition of agricultural crops online. Managers, planners, and just people use intelligence to track information online to predict time on road and possible needs to remain competitive at all times Djahel, Doolan, Muntean, Murphy (2014).

Detecting trends among artificial intelligence forecasting data allows combining intelligent location with marketing solutions and conducting targeted geotargeting for companies. Targeted geotargeting is the ability to manage the geography of marketing information for each user based on analytical decisions made by artificial intelligence. Each new offer to the buyer is made based on their intelligent location and the capabilities that the company can provide Shi, Zhang (2020).

Information technologies in our time has led to the development of geographic information technologies. For more than three decades, two-dimensional GIS have been developed, in which geographic data is represented by a set of flat objects (point objects - individual trees, bushes, etc.; linear objects - roads, highways, electric lines, pipelines; polygonal objects - forest tracts, fields). But as this technology penetrates more and more into the “masses”, it inevitably goes beyond the pale. MF Goodchild (2000). A map is a terrain model that describes the spatiotemporal relationships of objects and phenomena relative to the earth's surface Johnson (1990).

Maps allow one to view places and objects within certain boundaries simultaneously. They create a representation by visualizing the shapes, sizes, and positions of different objects and determining their dimensions in space. Maps contain these objects' necessary quantitative and qualitative characteristics and show spatial connections. Such meanings show the total value of the cards to be put into practice. Bürgmann,Rosen, Fielding (2000).

The term "map" comes from the Greek word chartes, which meant a sheet of papyrus for writing. Woodward, Harley (1987). It has long been customary to define a geographical map as a miniature image of the Earth's. But this definition is imprecise and incomplete. Firstly, it is true both in relation to any photograph of the image of Words surface and it relation to a landscape - an image of an area using the means of fine art. Secondly, it limits the tasks of the map to depicting the earth’s surface, while modern maps include in their content a wide variety of natural and socio-economic phenomena (for example, temperature and air pressure, national composition of the population); however, always shown in relation to the earth’s surfaces Nordström (2018). The mathematically determined construction of maps involves the establishment of a strict functional relationship between the geographic coordinates of points on the world's top layer and the rectangular coordinates and same points on the plane. This allows you to study spatial relationships and shapes of depicted objects using maps Steiniger, Weibel (2007).

Geographic maps convey phenomena using cartographic signs - special graphic symbols. These signs create a spatial image of reality on the map. The meaning of using cartographic symbols becomes clear when comparing the map with an aerial photograph of the same area. Cartographic signs “erase” many individual features of terrain objects and thereby impoverish the image Leander, Phillips, Taylor (2010).

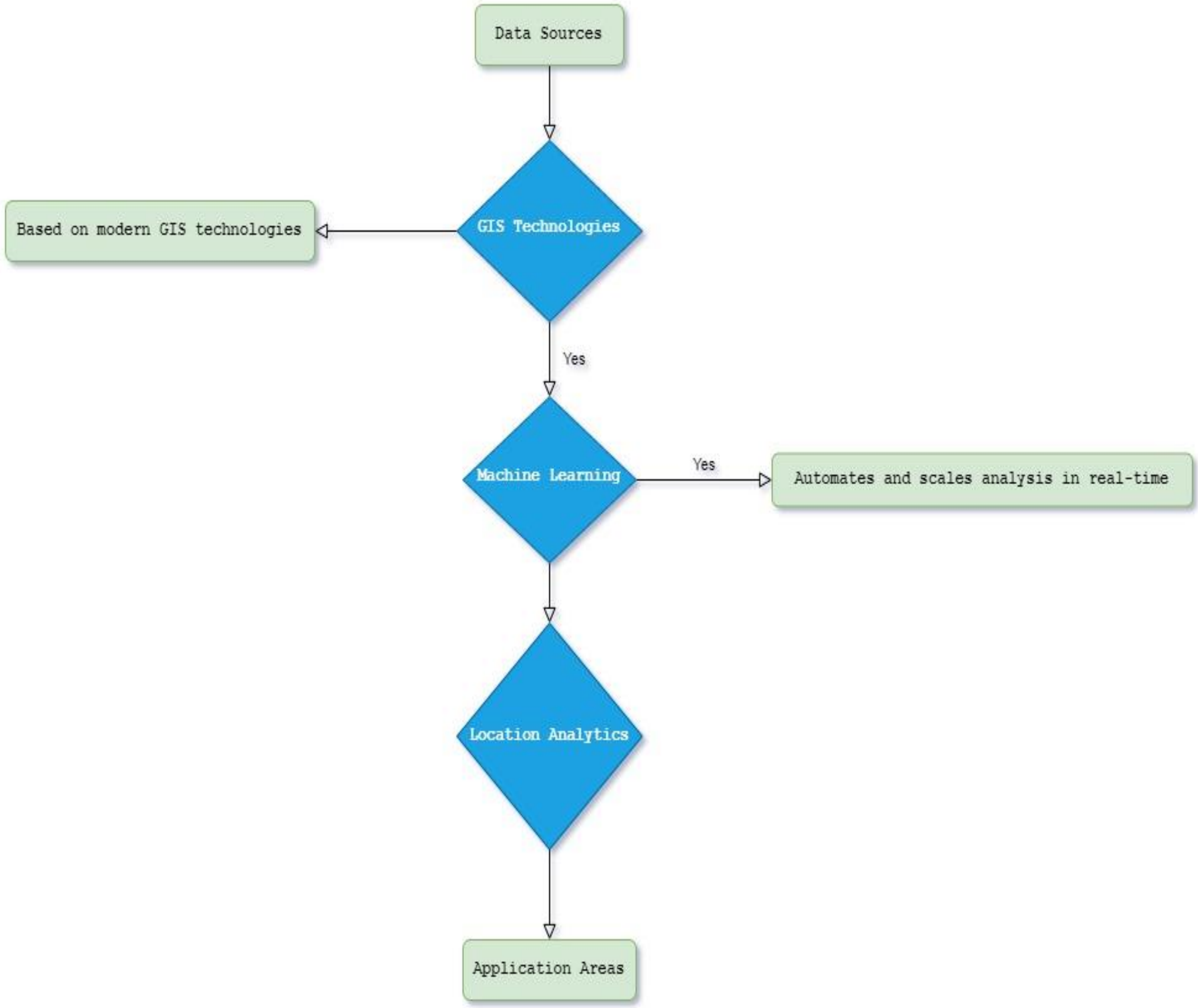

Figure 2 Variations steps industries with Intelligent Location Analytics and Machine Learning

To create a comprehensive visualisation of the world's surface on a map, it is necessary to reduce the image to view part or even the entire surface of the Earth, reproducing significant relief features at a reduction scale. In addition, the map must effectively depict the relief of the Earth's surface and convey topographic variations in a flattened image. It is essential, without limitation, only by the appearance of items and phenomena but also to indicate their internal properties for a deeper b understanding of the presented characteristics. It is necessary to illustrate the distribution of phenomena that are not perceptible to our senses, such as temperature, and to identify connections and relationships that are not directly perceptible.

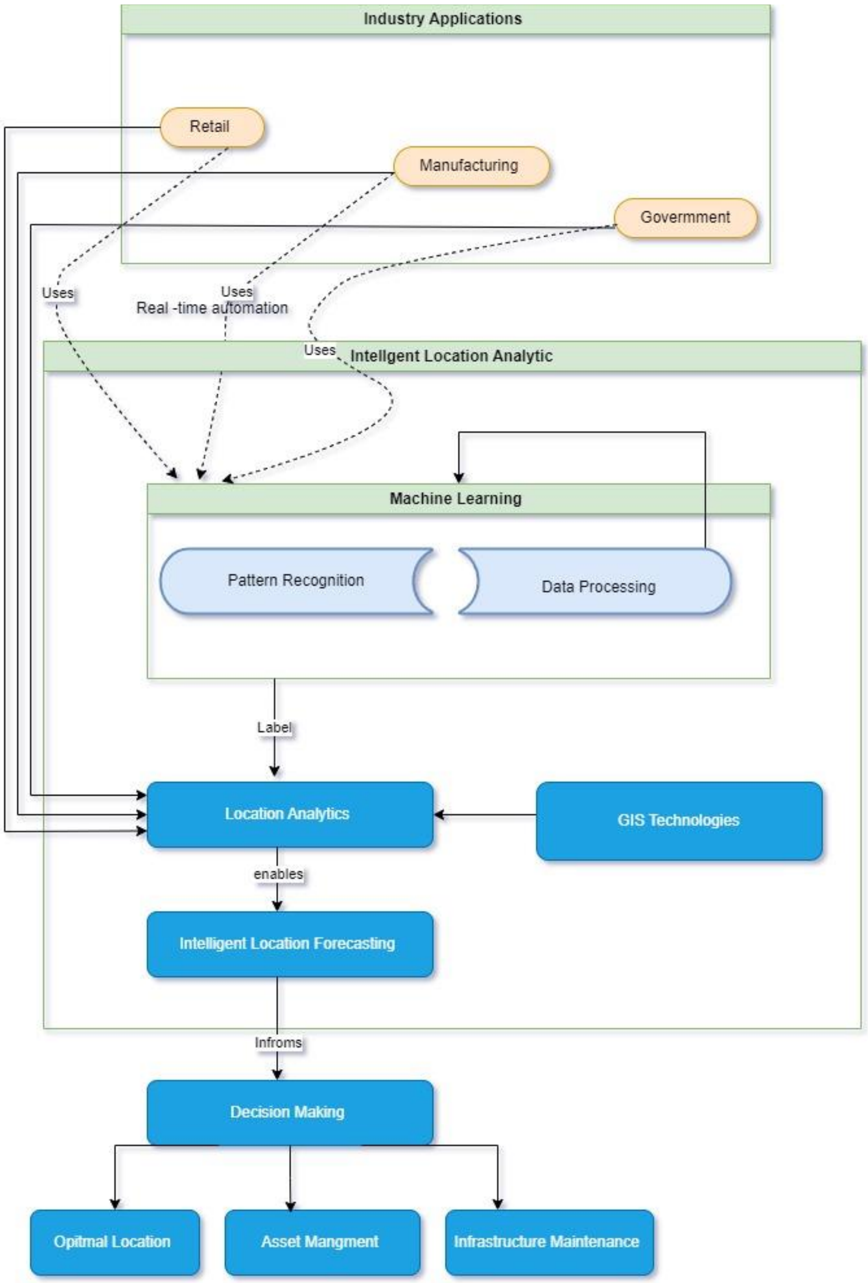

Figure 3 Steps for Intelligent Location Analytics and Decision-Making in Geospatial Applications

It is necessary to exclude unimportant aspects and details characteristic of individual objects or phenomena and highlight their standard and essential features through abstraction as mentioned in Figure 3. Finally, it is important to include key infrastructure elements such as buildings, roads, and other significant structures to show a full image of the built environment. This approach ensures the map is informative and practical, serving various purposes, from navigation to scientific analysis, while maintaining clarity and focusing on essential details.

1.3 Geographic Information Systems (GIS)

A Geographic Information System (GIS) is an opportunity to see the environment surrounding us in new ways. GIS is an up-to-date technology that displays and analyses items and occurrences on Earth. It combines database activities, like analysing statistics, with visualisation and spatial analysis provided by the map. The capabilities distinguish GIS from others and allow it to be used in an extensive range of tasks related to analysing and forecasting phenomena in the surrounding world, with awareness identification of the primary factors and factors and their possible results. GIS is a new, modern and practical approach to problem analysis and solution. It makes the analysis and prediction method automatic. Prior to using GIS, some technologies were able to summarise and comprehensively analyse geographic information to make the most effective choices using contemporary approaches and resources Malczewski (2004). GIS is used everywhere there is any kind of human activity—in the analysis of global problems such as over-population, land contamination, and natural disasters, or in solving tasks, like searching for the best way between different points or finding where the pipeline laying or other tasks connected to geographical technologies.

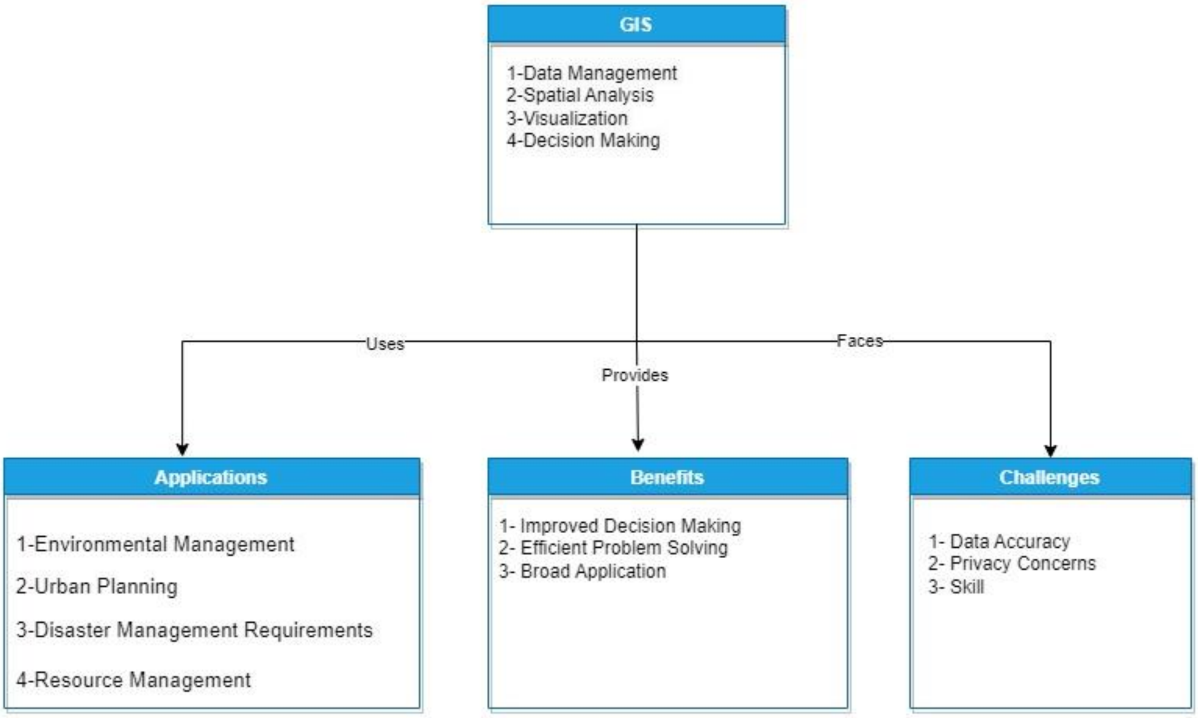

Figure 4 GIS Applications, Benefits, and Challenges

1.4 3D visualizations and improved utility management in ArcGIS Pro

Managing and understanding complex utility infrastructure systems in ArcGIS is enhanced by 3D visualisations that show and help identify potential problems that need improvement. ArcGIS, for comprehensive data management, supports a variety of workflows such as creating geometric representations and 3D visualizations of utilities Österman (2014).

For data that is not in 3D format, 3D bases maps provide the ability to create detailed underground and surface utility features. Using ArcGIS Pro or Scene Viewer, layer properties can be adjusted and including underground navigation can greatly improve the visualization of utilities Schokker, Sandersen, Beer, Eriksson, Kallio, Kearsey, Pfleiderer, Seither (2017). This approach is important for effective management and the collaboration of different utility systems in different industries.

ArcGIS Pro 3D pipeline visualization improves utility management and increases understanding and management of complex infrastructure systems. Users can get a realistic representation of the physical world by creating detailed 3D visualizations, especially for infrastructure projects. In the context of pipelines, simulations such as the flow of water or gas through pipelines are important, and this in turn improves decision-making by helping to understand spatial relationships and potential conflicts better, facilitating planning and maintenance. Of course, emergency response is also a big advantage. ArcGIS Pro further enhances utility management capabilities with the Utility Network Management extension, which provides modelling, visualization, analysis, and more tools Srivastava (2020).

1.5 Components of GIS

A GIS has five key components: hardware, software, data, people, and methods. Hardware: This is the computer running the GIS. Today, GIS operate on various types of computer platforms, from centralized servers to individual or networked desktop computers. GIS software contains the functions and tools needed to store, analyze, and visualize geographic (spatial) information. Data is probably the most important component of a GIS. Spatial location data (geographic data) and associated tabular data are important to GIS systems. The data may be collected and prepared by the user themselves or purchased from suppliers commercially or otherwise. In the process of managing spatial data, GIS integrates spatial data with other types and sources of data and can also use AI to speed up and automate tasks, quickly extract information from huge amounts of data, and save time Zhu, Wright, Wang (2018).

Performers: Widespread use of GIS technology is impossible without people who work with software products and develop plans for using them to solve real problems. GIS users can be both technical specialists who develop and maintain the system, and ordinary employees (end users) to whom GIS helps solve current everyday affairs and problems Yang,Wong, Yang, Kafatos, (2005). Methods: The effectiveness (including economic) of using GIS largely depends on a properly drawn up plan and work rules, which are drawn up in accordance with the specific tasks and work of each organization.

1.6 How GIS works

A GIS stores all information about the natural world as thematic layers. They are aggregated based on location. Any geographic information contains various data about the spatial location - this can be a link to geographic and various coordinates, addresses, and indexes. A geocoding process is applied to determine the desired features' location automatically. Such a process quickly determines where the desired object is located on the map, such as a store or flood location. Also, it builds a route, simplifying and finding a more convenient road to optimally reduce the time to reach the desired one (Wise, 2018). Three-dimensional GIS can be used for maps of any scale and purpose. 3D GIS software is used only for highly specialized geographic information purposes.

1.7 Formation of the relief in a completely new way

Formation of the relief is the simplest and most used technology. It is used not only in specialized geosystems, but also in numerous demo programs, games and simulators. Basically, the data for this 3D GIS class is a DEM and a surface view. Small objects such as trees, and houses can also be additionally specified. Showing terrain features is the main function. This is realized by flying the camera over the surface of the earth at bird's eye height. Using programs of this class, both large-scale and small-scale maps can be presented. The difference is in the degree of generalization of real geographic data Pepe, Costantino, Alfio, Vozza, Cartellino (2021).

1.8 Three-dimensional cadastral systems and visualization of urban areas

Three-dimensional cadastral systems and visualisation technology have become most widespread due to great practical need. Cadastral systems and urban planning and management systems are widely used in the national economy for various purposes. For this type of system, large-scale geographic and topographic maps are used primarily. The data can be any type of object, based on the detail of the structure and also its particular purposes: constructions, roads, various communications, forest plantations, any small objects, such as lighting poles and other objects used in urban management. Accordingly, the primary function of such systems, in general, is to obtain a variety of information on each object, the possibility of various selections and data aggregation. In three-dimensional urban GIS, the ability to conveniently inspect the layout and location of the objects and other functions inherent only in three-dimensional systems is added Döner, Bıyık (2022).

For urban 3D GIS, one of the most important functions is the smooth increase/decrease of image detail. If a 3D system developer plans to display the appearance of objects, then it is necessary to store textures of all types of objects and perform non-distorting transformations with them in real time Ying, Guo, Oosterom, Stoter (2015).

3.ENHANCING KERAVA'S PIPELINE MANAGEMENT WITH 3D GIS

Today, 3D modeling has many applications and of course in GIS. The project I propose can be used in the Kerava municipality: 3D model of the pipeline.

This project will demonstrate efficiency, reliability and improve the operation of pipeline systems. The aim of the project is to showcase the productivity, reliability and improvement of the operation of pipeline systems. The main task of 3D modelling is the visualization and development of the pipeline. 3D models will help identify potential problems and improve the design. A three-dimensional representation of the pipeline, visualization, will facilitate understanding of the design, assess strength and safety.

Modeling will also help facilitate work with documentation and reporting.

To create a 3D pipeline modeling in the municipality of Kerava, the first step is to gather data on all pipelines in the municipality: GIS drawings, maps, technical parameters, locations, and characteristics of pipes. Choose the right software, such as ESRI ArcGIS. Currently, the pipeline maps are in QGIS. This means importing data (drawings and maps) into the necessary software.

Start creating the 3D model using imported data. Create a 3D depiction of the pipes and all related details. Connect them into one system based on all technical characteristics (direction, pressure, etc.).

3.1 Conduct testing and create documentation

This chapter focuses on the practical implementation of 3D GIS and AI technologies in pipeline management in Kerava. The main goals are to develop accurate and reliable 3D pipeline models, optimize system operations, and improve maintenance and risk management strategies. Using GIS and AI capabilities, the project aims to improve the monitoring and diagnostic capabilities of pipeline systems, making maintenance planning more efficient and predictable.

3.1.1 Pipeline Optimization

The author’s interest in the field of GIS AI and 3D pipeline modelling is very diverse. One of the main goals is to develop accurate and reliable 3D pipeline models using GIS and AI in Kerava municipality. This includes developing algorithms, analysing, and classifying objects in 3D. Also, using GIS AI will help to optimise operations of pipeline systems: monitoring and diagnostic systems, making maintenance plans easier, predicting fixing and enhancing prevention and risk. GIS AI will help identify vulnerable sections of pipelines and predict the likelihood of accidents, which will facilitate the development of risk management strategies. It is also important to create documentation to ensure ease of use of the 3D GIS and AI system for pipeline management. Documentation makes operation and maintenance many times easier, provides clear guidance and troubleshooting tips. Facilitates training of new users, ensuring that all stakeholders are well prepared to use the system effectively.

3.1.2 3D GIS and AI in Pipeline Development

The interest in the topic and motivation is that technology is developing rapidly, and the author is attracted by the possibility of using GIS AI to create a 3D pipeline model to create an improved infrastructure in the Kerava municipality. Creating a 3D model is an innovative solution that will replace conventional maps, increase operational efficiency and safety, save time, and, in the future, finances.

Of course, the interest in the topic is also connected with the author's professional ambitions, the desire for development in the field of engineering and geoinformatics. Learning to create 3D pipeline models using GIS and AI is a valuable skill and knowledge that will benefit their careers both in Kerava Municipality and in their own businesses. All the above factors form the interest in the topic and motivation for studying and developing in the field of creating 3D models of pipelines using GIS and AI.

Three-dimensional GIS can be used for maps of any scale and purpose; now, 3D GIS software is used only for narrow geographic information purposes.
Formation of the relief in a completely new way what is the simplest and most commonly used technology. It is used not only in specialized geosystems but also in numerous demo programs, games and simulators. Basically, the data for this 3D GIS class is a DEM and a surface view. Small objects such as trees and houses can also be additionally specified. Showing terrain features is the main function. This is realized by flying the camera over the earth's surface at bird's eye height. Using this class's programs, large-scale and small-scale maps can be presented. The difference is in the degree of generalization of real geographic data Du, Zlatanova (2006).

Three-dimensional cadastral systems and visualization technology have become most widespread due to great practical need. Cadastral systems and urban planning and management systems are widely used in the national economy for a variety of purposes. Large-scale geographic and topographic maps are mainly used for this type of system. The data can be any type of object, depending on the detail of the system and its specific purposes: buildings, roads, various communications, forest plantations, any small objects, such as lighting poles and other objects used in urban management. Accordingly, the main function of such systems, in general, is to obtain a variety of information on each of the objects, the possibility of various selections and data aggregation. In three-dimensional urban GIS, the ability to conveniently inspect the layout and location of the objects themselves and other functions inherent only in three-dimensional systems is added Shojaei, Kalantari, Bishop, Rajabifard, Aien (2013).

For urban 3D GIS, one of the most important functions is the smooth increase/decrease of image detail. If a 3D system developer plans to display the appearance of objects, then it is necessary to store textures of all types of objects and perform non-distorting transformations with them in real-time. Billen (2000).

3.2 3D modelling pipelines ArcGIS pro

Improving the capabilities of GIS systems requires integrating pipeline networks using ArcGIS Pro and machine learning, including GeoAI and cloud technologies. This is necessary to improve operational efficiency, improve decision-making and failure prediction, and optimize maintenance schedules. GeoAI can analyze spatial data from convolutional and recurrent neural networks, examining the ArcGIS Learn, PyTorch, and TensorFlow Learn libraries for compatibility with spatial analysis. It is also important to assess the scalability of a cloud platform like AWS and the ability to integrate it with ArcGIS Pro Srivastava (2020). All data for the pipeline network transfers into ArcGIS Pro, to be structured for examination using a tool such as Utility Network. This is necessary to define relationships and coherence. Machine learning models are trained using pipeline data stored in the cloud. Integration with ArcGIS Pro provides continuous monitoring and predictive alerts. Feedback mechanisms are established for continuous improvement and enhanced safety in pipeline operations. Arnold (2023). As illustrated in the provided picture (Figure 5)

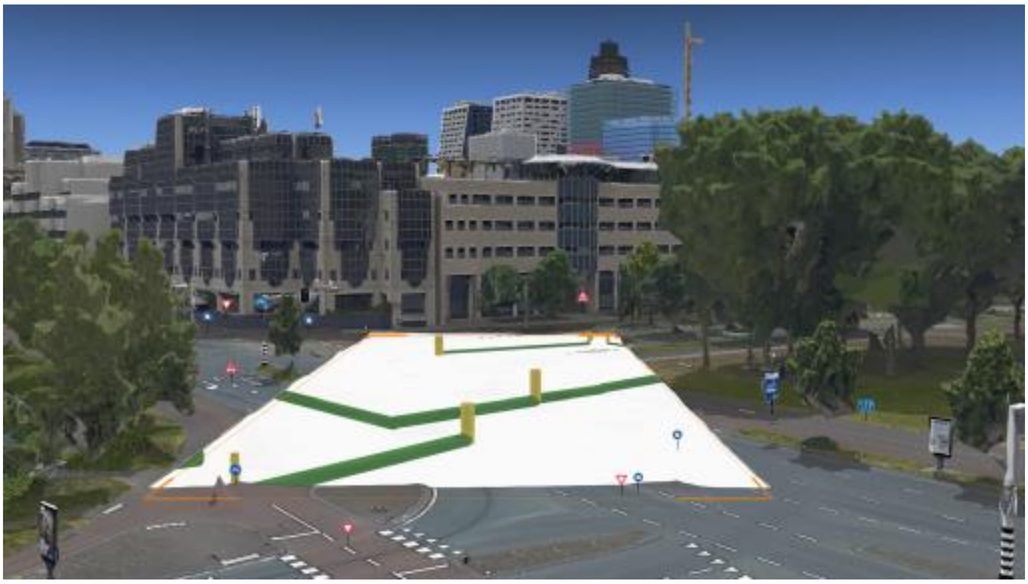

Figure 5 3D Urban Visualization with GIS and Machine Learning Integration Srivastava, (2020). Arnold, B. (2023

3.3 Research Questions

The study examines these vital aspects of current data management and infrastructure optimization, which are addressed by the study approaches. The purpose of these examinations is to unravel many of the cloud server platform dimensions, geographic information systems (GIS), issues in data management, technological optimization and secured data practices. Moreover, this research aims to investigate these issues and unveil important findings for innovative strategies, appropriate methods and effective data management approaches in the context of cities. The research questions that have been delineated are as follows:
Cloud platforms play an essential role in effectively managing large volumes of data by offering scalable storage solutions and advanced analytics tools to simplify data management processes. The functionality of GIS platforms has been adapted analysis and illustration of geographic data. Based on improved data analysis, the geographic context embedded in data sets allows us to make informed decisions. Data management systems in the cloud can face data integration and performance issues.

Organizations can quickly and effectively address these challenges by implementing robust data integration strategies and optimizing system performance. AI and machine learning are improving the management of big data and data in the cloud. The central aspect of using cloud servers is to ensure data security, confidentiality, and integrity. Therefore, implementing various security procedures, such as data encryption and access control, ensures the security of data stored in the cloud environment.

3.4 Research Aims

The aim of the thesis is specifically to contribute to the realm of water and sewage network management in the city of Kerava. The primary focus is clustered around the development of an exemplary and integrated system that leverages the capabilities of Infrakit. This is a platform that is more than any tool; it is a truly powerful tool that can simulate, record and manage infrastructure data with high efficiency and accuracy Infrakit.(n.d.) Sustainability and scalability will improve with algorithmic improvements and strategic implementation. This will be the basis of a comprehensive and adaptive mechanism that is capable and ready to cope with the dynamic needs of life in urban infrastructure. First and foremost, the project has a very strong focus on resource optimization, improving data efficiency, service delivery standards, data-driven decision-making, and collaboration among stakeholders. The idea of the projects is to originate the radical transformation of the urban infrastructure of the city to become efficient, powerful, and ecologically friendly.

3.5 Revamping Urban Data Management for Kerava's Infrastructure

The reason for embarking on the initiative is due to the urgent and immediate need for updated and effective data management methods that are applicable to all urban infrastructure networks within the framework of the city of Kerava. Infrastructure, like water and sewage networks of urban areas worldwide, face challenges in successfully managing and preserving as the population grows, the pattern of urbanization changes and the technology environment shifts Daulat (2024). The complexity of the tasks leads to a transformation of approach to more progressive and smart tools for working with data. The goal is to develop technologies such as Infrakit, that could overcome the biggest challenges the local authority currently has. Therefore, cloud computing will be used. The issues associated with these problems include the sharing of data, the variety of formats, limits of integration and the essential demand for more careful approaches to the presentation of data. This project targets the data unification from different sources, as well the homogenization of the data format and administration procedures through the application of the most advanced software tools and data management principles.

The establishment of finely-tuned data management system is a game changer, for example, in addressing deficit woes, asset management, and infrastructure improvements. This initiative will be geared to offering better services to people and foster a sustainable and resilient urban infrastructure network by providing access to information on all the infrastructure Tansel & Zhang (2022) Finally, the plan bears complete harmony with the overall goals of smart cities which are to build cities that are environmentally friendly, resourceful, and very innovative when it comes to managing urban systems. This project lays the basis for more intelligent smartcity infrastructure by developing a smart platform that can integrate information from multiple sources and apply advanced algorithms for analytics and visualization Gupta (2020). The objective of the project is to serve as a basis for changing data management methods, resource allocation, service delivery, and innovation for the management of the city's infrastructure issues in the city of Kerava, as illustrated in the provided picture (Figure 6). The recipe seeks to be a tangible consequence of the city’s sustainability, resilience, and long-term planning through the application of advanced technologies and new methods.

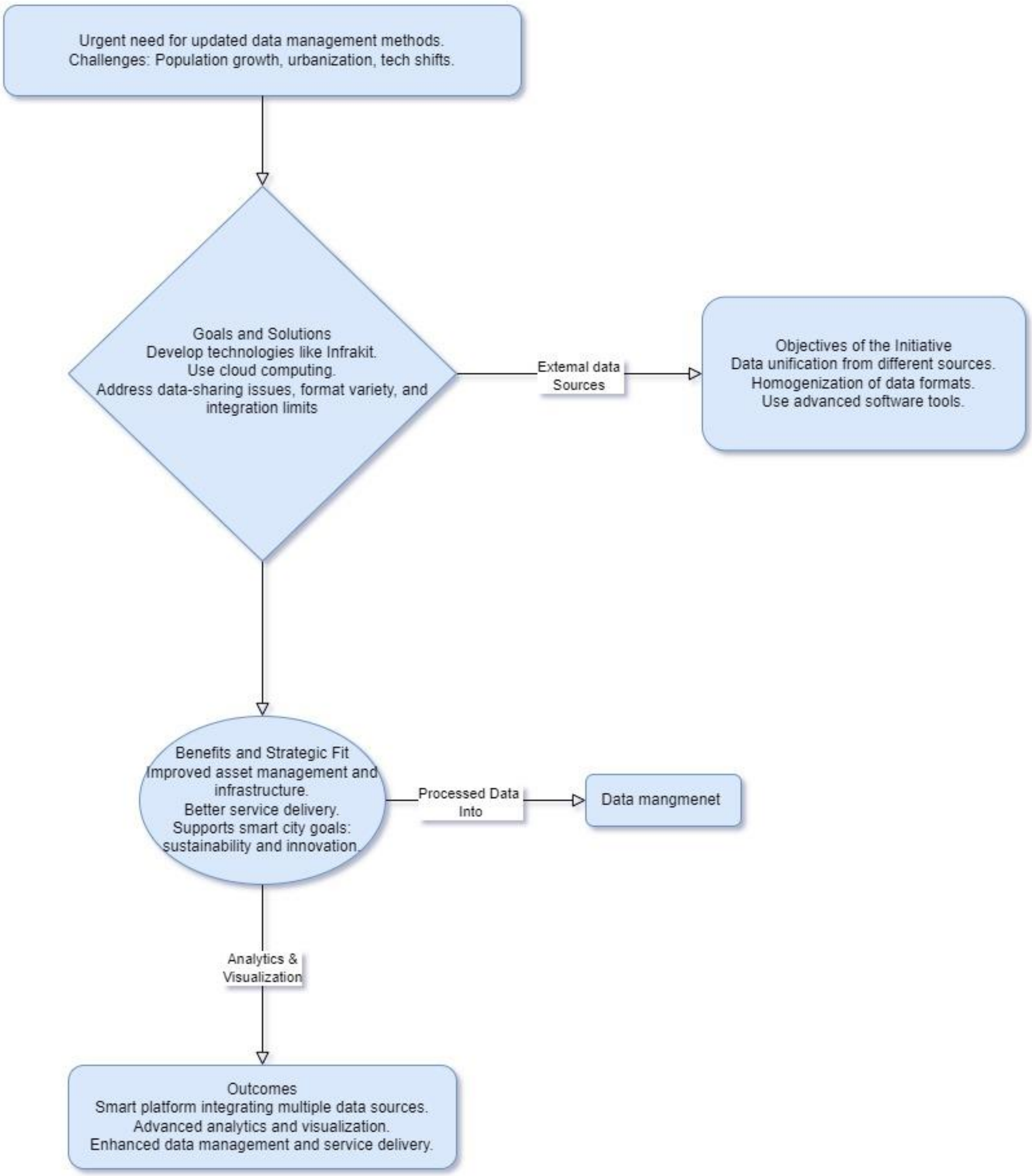

Figure 6 Strategic Data Management for Urban Infrastructure in Kerava

4 LITERATURE REVIEW: REVOLUTIONIZING DATA MANAGEMENT PROCESSING IN URBAN WATER

In the modern era, it has become evident that the process of efficient data management has immense significance for the urban water and sewage networks. With smart city strategies and increasing technological innovations, it is becoming essential to standardize the way the data is managed in order to be certain of what the governance of water services would be in the long run. In this respect, well-implemented data management processes, being the individuals who are solely entrusted with the stable and smooth management of the urban sewage network and water, are imperative. The shift from conventional 2D data management approaches to modern 3D model systems is a key movement intended to improve urban water services' effectiveness, dependability, and sustainability.

In the literature review, we examine the complex challenges that the water and sewage companies face as they strive to manage their infrastructure data and operations efficiently, considering the case of the city of Kerava, along with the possible solutions. Okwori et al (2021) propose a conceptual model for urban water pipeline management using a data-driven approach. This framework highlights the critical role that sensors, historic maintenance records and geographic data play in providing the foundation for advanced asset management techniques. Using the analytic techniques and advanced machine learning methods would allow water companies to base their decisions regarding the maintenance, rehabilitation and replacement of the system and improve its efficiency. Joseph, Sharma, and Van Staden (2022) introduce the ideas of innovative cities, in which systems to control and handle urban waters have already been integrated and managed using the artificial intelligence (AI) and machine learning. Through arranging the sensors and IoT tools along the network, there emerges an opportunity to get the data in real-time, analyze it, detect the leaks, estimate the equipment failures times, and boost water distribution. Through strategy, not only the system efficiency will be enhanced but there will be less leakages in the operating pipe network as well as this will lead to saving operation costs.

4.1 Data Pipeline for Wastewater System Operation

Effective management of wastewater systems puts a strong emphasis on the development of efficient data pipelines as well. Therrien, Nicolaï and Vanrolleghem (2020) point out the necessity of unified data collection protocols and interoperable data formats within this system. This permits the integration of diverse data channels and their aftermath to be analyzed for the decision-making process. Secondly, the writers push for the application of sophisticated data analytical tools that include predictive models and anomaly detection algorithms. These devices facilitate real-time monitoring of the systems and also help to apply a proactive maintenance strategy so that the companies can have better resilience against the risks and existing aging infrastructures. Wastewater systems, which are complex networks, comprise a great deal of monitoring and maintenance activities to maintain their sustainable performance quality and avoid environmental degradation. Nevertheless, data management poses major problems because the systems generate a lot of data. Therrien et al. (2020) recognize the idea that the system of information collection protocols should be standardized so that measurements are uniform as well as credible. Establishing the standards will cause vacant positions to struggle to maintain data quality, and as a result, there will be wrong analysis and decision-making.

Additionally, interoperable data formats are vital for enabling information sharing and combining different systems and platforms Okwori et al. (2021) highlight that standardized structures to facilitate the interoperability of shared data, as well as successfully analyzed data are required. This ability to match up creates the platform for utilities to gather data from different data sources, including sensor networks, SCADA systems, and geographical information systems (GIS), to comprehensively understand how the system performs and behaves. Aside from standardizing data collection procedures and formats, they also suggest that data analytics tools should be incorporated into the system upgrade operations for maintenance improvement. It enables water companies to anticipate any problems in the system that may occur in the future and thus repair the damages through preventive diagnosis and maintenance. Unlike other types of algorithms, the anomaly detection algorithm can detect departure from the norm in the performance of the system that, in its nature, triggers the request for additional interventions.

By implementing high-quality data pipelines and using up-to-date analytics tools, water enterprises can boost their operational stability and protect their infrastructure against aging issues. Predictive maintenance techniques lead to preventive interventions intended to avert the evolvement of issues into critical ones that might lead to machine failures, thereby minimizing machine downtime and increasing the machine's ease of access to services. Besides, its early detection of failures and abnormalities makes the system monitoring more reliable and better ensures that corrective measures are taken in time Joseph et al. (2022). The establishment of a good data pipeline constitutes one of the most important aspects of wastewater system management. The application of standardized data collection processes and interoperable data formats results in a consistent portion of the data, which allows for easy data transmission and interconnection between different systems or platforms. Water companies can implement sophisticated data analytics tools, which will increase system monitoring, predictive maintenance, and operational resilience, thereby cutting down on the dangers of old infrastructure and helping to ensure the reliability and performance of wastewater systems. Municipal drainage networks are very complex: this is not only their burden but also their advantage; they have to maintain pipes in good shape and face urbanization-induced pollution. Wang et al. (2021) stress that the management of this network is not simple and emphasize the need to adopt a holistic approach to managing urban drainages. This strategy involves the fusion of hydraulic modelling, GIS, and remote sensing technologies in the process of assessing system vulnerabilities and ranking infrastructure investments in priorities. Through anticipation of these problems, water companies will be able to decrease flood risks and protect water quality within the cities.

4.2 Forecasting Pipe Failures in Potable Water Networks

The capability of forecasting pipe issues in clean water infrastructure systems is a complicated issue resulting from the multiplicity of the factors affecting them. Barton, Hallett, and Jude (2022) discuss this issue, focusing on the inability of the current predictive modelling methods to capture the complexities undergirding future pandemics. They assert that traditional methods, typically older age-related models, are inappropriate to describe the complicated interrelations of environmental factors, material parameters, and operational conditions. This, therefore, can result in inaccurate predictions, and such can cause costly misfortunes.

However, this challenge is quite enormous because of the constant use and old age of these networks, which makes the pipes easily damaged during the process. The latest age-related disintegration models are appropriate when considering the complex interdependence of the factors or general rules. Elements such as water quality, soil texture, and operating stresses play a huge part in assessing the pipe lifespan with impact. By doing so, severe inaccuracies in the determination of pipe breakdowns might occur, meaning that the security of public distribution systems will be affected. In order to tackle these difficulties, the authors offer the use of modern data analytics solutions, including machine learning and probabilistic modelling (Barton et al., 2022). These instruments utilize a more refined approach to panning through immense databases and outlining trends that normal statistical methods may not allow their users to notice. Through the use of machine learning formulas, it is possible to understand all the intricate relationships of multiple factors of pipe integrity along with their nonlinearity.

These machine learning algorithms, including such as random forests or neural networks, are nothing, but they have the power to learn from historical data and adapt themselves to the varying conditions besides the time (Tansel & Zhang, 2022). This can be realized by training models with wide datasets that contain not only pipe age but also environmental factors and operational factors. With that, a result of the development of more predictive models than the ones that predict only pipe age is a possibility. These models can then be assessed for pipe failure possibility in tougher conditions for later prioritization. Another key area that is probably going to provide an effective prediction of pipe breakages of drinking water networks is probabilistic modeling. Probabilistic models reflect imperfections in data and do not necessarily provide deterministic predictions but probabilistic estimates of failure. This approach enables water utilities to be more equipped by first thinking about the inherent uncertainties that we associate with predicting pipe failures.

4.3 Integrated Multi-Asset Infrastructure Management

Integrative multifunctional infrastructure administration management, as such, is a deeply involved issue for water companies, which demands the capture of the wide array of interdependencies between pavement, sewer and distribution networking systems. Daulat et al. (2024) address this complex matter, providing clarity and expounding possible solutions. They are very specific about the need for interoperable data storage and management systems and also recommend shared decision-making processes in order to realize the highest industrial efficiency. Through holistic solutions, water companies can achieve outstanding results, thereby ensuring return on investment and greater resilience of infrastructural networks. Management of multiple facilities involves requirements not given to simple infrastructure assets like interdependencies and coordinated maintenance and operation. Unlike single asset management methods, integrated multi-infrastructure asset management requires a viewpoint that considers how the different systems interact and influence each other (Okwori et al., 2021).

The integrated data systems and databases working together can be thought of as the pillar of advanced multi-infrastructural assets management. Such systems of information allow the smooth flow of data and integration sharing between various kinds of assets that can accomplish a holistic assessment and choice. Daulat et al. (2024) emphasize that the use of standardized data formats and protocols is paramount to ensure compatibility and interoperability between different systems. Information systems that are not yet isolated and have stakeholders cooperate and synchronized apply a much more effective integrated approach to asset management. Active decision-making together and within a team is the key to successfully managing the multi-structure inputs. Daulat et al. (2024) suggest the engagement of all stakeholders, such as engineers, planners, policymakers, and community members, in the asset management decision-making process. Involving different voices in the conversation, water companies will design comprehensive programs that account for diverse needs and equilibrium conservation whilst seeking to realize the full potential of investments in infrastructure. Like teamwork, collaborative methods pursue transparency and increase accountability levels, which is widely credited with the formation of trust among interested stakeholders and the delivery of buy-in for initiatives being proposed (Wang et al., 2021).

Asset management, which encompasses both the allocation of resources and the prioritization of long-term objectives, becomes more profitable with a holistic approach, and thus increases the worth of investments for water companies. Daulat et al. (2024) bring out that a successful asset optimization should engage everything that the lifetime asset entails, right from budgeting and design to building, running, and managing the asset. Through making use of predictive maintenance approach and analytics predictions, water companies will be successful in deferring asset degradation and downtime interruption, which will, result in lowering of the asset lifecycle costs. One of the dedicated multi-functional facility systems has the ability to increase the multifunction of an asset infrastructure. The water utilities can appreciate the systems' dependencies; thus they will discover the vulnerabilities and develop the adaptation strategies accordingly. Wang et al. (2021) advocate for funding resilience through better reliability, backup systems, along with emergency response to enable infrastructure networks to withstand occurrences of disasters, climate change and any other interruption that come into being. A proactive approach to face water infrastructure vulnerabilities will contribute to the water company providing a continuous supply of water services and a much shorter duration of interruptions in the service.

4.4 Strategic Water Loss Management

Water loss management is an essential point that contributes to the sustainable development of urban infrastructures. Bozkurt et al. (2022) underline the improvement of water planning and support for water saving along with the introduction of real-time monitoring and leak detection technologies. This approach proposes the development of a kind of model that would involve hydraulic modelling, GIS analysis, and leak detection sensors in detecting and targeting the areas of maximum leakages A strategic water loss management policy incorporates the fundamentals of responsible planning techniques that also include leak searching in the distribution system to recognize and minimize water losses. Technology that is real-time, in addition to leak detection, is emphasized by the authors Bozkurt et al. (2021) in this process of development. By using sensors and devices in the networks of the IoT, water utilities can constantly monitor the flow rates and pressure levels of the water. This enables the detection and pinpointing of leaks at exactly the time they occur. The proposed water loss management model will be linked with other data like hydro-model and GIS analysis, just to emphasize the point that good information is vital for producing better leak detections. The hydraulic simulations that they connected with geographical information show where most leaks start, and then they direct inspections and maintenance in that direction Gupta et al. (2020). Moreover, the sensing of leak detection helps in understanding the condition of the piping online, and this information on the pipe infrastructure condition can help us to respond to the leak immediately in which case we reduce water losses.

Installing effective water loss management strategies can have multiple advantages for water utilities and the populations they serve. Utilities could stop experiencing revenue losses associated with unbilled or unaccounted-for water by reducing the water losses. Similarly, water conservation helps to guarantee enough supply for present communities and for those in the future. In addition, lessening water leakages should ease water treatment plant operations as well as the inefficient water infrastructure that arises as a result, hence more savings and improved operational efficiency. Strategic water loss management is needed to ensure maximum efficiency while also maintaining the sustainability of the urban water systems. Bozkurt et al. (2022) claim that an integrated approach that includes real-time monitoring, hydraulic modelling, GIS analysis, and leak detection technologies can ensure the plugging of hotspots. Water utilities can effectively prevent revenue losses, save the precious water supply, and strengthen the water distribution system through proactive water loss management measures.

4.5 Smart Water System for Improved Resource Management

Water resource management, with its disruptive technologies, is a valuable source for increasing water efficiency and sustainability. Gupta et al. (2020) review different applications of smart water, such as the IoT, AI, and big data analysis, to help water utilities optimize water distribution and treatment processes. These technologies decisively shift the paradigm of utility operations towards an environmentally sustainable and economically efficient approach. A smart meter is the cornerstone of smart water systems, which facilitates the exchange of data concerning water usage and consumption for utilities and consumers in real-time lo Storto (2020). The application of smart meters all over the distribution system improves utilities' ability to monitor the usage of water in real-time and reveal leaks and unusual behaviour in a prompt manner. In this way, water utilities can implement target interventions like leak repair and demand management measures to minimize water losses and improve system performance.

IoT leverages sensors and technologies to monitor IoT-based water infrastructure continuously. It does so through monitoring the condition of the pipes, valves, and pumps. The foregoing approach can even identify many anomalies like pressure decrease and flow disturbance leading to the invisibility of leaks or technical faults. By anticipating and resolving any problems before they pose a threat, utilities can provide a cost-effective water supply and uninterrupted services with great reliability and resilience of the supply system. Predictive analytics in this area of study uses machine learning techniques such as advanced algorithms and AI to analyse a huge amount of information. In this way, he may forecast future water quality, demand, and supply. Through the acquisition of historical data, weather forecasts, and other significant factors, the utilities can make projections and plan operational decisions and resource allocation effectively. They, therefore, experience the ability to prognosis and react to disturbances in the system or mismatches and face water services delivery Gupta et al. (2020).

4.6 Hydrological State Modelling in Sewer Systems

The implementation of the integration of hydraulic-water models and real-time information from sensors would be a promising and reliable means to ensure better accuracy in water quality predictions and enable the establishment of pollution detection system events. This approach is beneficial given that it gives water companies a firm understanding of how pollutants move within sewer networks. They will be able to enforce pollution control measures and ensure the quality of receiving water bodies. Water quality management in sewer networks is composed using of multiple steps and different processes within them is complex for water nature that is dynamic Jia's et al (2021) research explores that the modeling methods used in traditional approaches to this problem usually are not sophisticated enough to include all the factors simultaneously, hence the necessity of new approaches providing better solutions to the problem. The combination of hydrologic and water quality models with real-time sensor data not only represents a breakthrough, it will also help us build better plans for pollution prediction and management. Employing the services of sophisticated model projections along with immediate data intelligence, the water entities will be able to anticipate where pollution emerges and devise a prompt response to limit the environmental threats (Babamiri, Pishvaee, & Mirzamohammadi, 2020). The adaptation of this proactive approach is not only instrumental to the resilience of sewer networks but also helps develop a water management pattern that is sustainable and ecologically oriented

In integrated services models where performance is optimal, not only are traditional performance metrics of use, such as water loss rate or customer satisfaction score, but also the full-scale efficiency gains derived of the integrated services model Storto (2020). These companies can utilize DEA techniques as one of the best data to analyze on parallel network that can be mandatory for water companies to run a normal business by cost saving and performance improvement along the entire water service value chain. Efficiency measurement in urban water services is a multidimensional defects encompassing the custom spectacle of effectiveness evaluate. Traditional metrics help immensely in analyzing the performance of distinct domains of water services, albeit they do not succeed in logging the connectedness or synergies among various operational domains even when functionally integrated. A parallel network DEA models provide a robust platform for integrated water services evaluation that takes all inputs and outputs into simultaneous consideration Therrien, Nicolaï, & Vanrolleghem (2020). Through analyzing the efficiency frontier of parallel network operations, water companies are better positioned to improve resource allocation, performance, and service delivery. This strategic method enables water companies to make most from their investments, and thus, improve the system well-being.

4.7 Sustainable Water Management in Municipal Corporations

Municipal corporations act as the main actor that guarantees the fair circulation of water while paying attention to the needs of marginalised communities in urban areas. Dutt and Punniakotty (2021) elaborate on sustainable water management practices employed by these corporations, while putting emphasis on equity and social inclusion factors. The central issue is the recognition of staff motivation and involvement in all the processes related to the water management decision-making process. The municipal corporations are expected to have an open dialogue with its residents, stakeholders, and community organizations as they discuss water resource management, infrastructure development, and policy formulation. Through enabling dialog and complaint, corporations would be able to learn about the specific water-related difficulties in various communities and develop their solutions to fit those needs. However, as noted by Dutt and Punniakotty (2021) it seems to be important to include community involvement, since community's decision-making authority in water management practices is also emphasized by them. Involving different stakeholders in decision-making also helps to guarantee that the interests of all the society groups are taken into consideration. Through communities' participation in water policy making and implementing projects, the cities authorities develop the trust, ownership, and social justice in water service provision.

The development strategies that guarantee sustainability within the water sector ,along with capacity building initiatives, emerge as the key factors in achieving these goals. Municipals should start these processes by having education, training and development programs of their staff to develop tech expertise and know-how of the municipal corporation. Furthermore, capacity building programs also strive to equip the locals with the skills and resources that will enable them to be engaged in the use of water sustainably and water pollution prevention. Through staff and community capacity building programs corporations can create a climate in which organization and population will adapt to the changing conditions in water management. Dutt and Punniakotty's holistic approach consider the technical and non-technical issues, which are social and economic dimensions in sustainable water management. Local governments can bring together environmental concerns with social equity and economic development aspirations and as a result, generate synergies and hence, ensure overall resilience and well-being. Green infrastructure projects not only improve water quality and attenuate flood risks but also make jobs and build a livable community. Unsurprisingly, adequate water governance also allows for social cohesion where stakeholders and authorities are supportive of inclusive and participatory structural governance. Through the process of listening to and valuing all expressions in the decisions making, municipal corporations can be able to strengthen the ties between its residents and make them responsible for water resource stewardship.

In general, the aforementioned literature emphasizes the multifaceted challenges which the water and sanitation companies confront in coordinating their infrastructure data and operations. Embracing the new 3D management paradigm in the proposed thesis project can be the key to unlock better and faster data handling. Through advanced technology like deep learning, cloud computing and GIS, water companies can gain strength in their decision-making process and resource allocation optimization and boost the resilience and sustainability of urban water infrastructure systems.

4.8 Needs and Technology Assessment

Sustainable growth of municipalities in the present-day urban development, requires strategically organized resource and infrastructure management practice. Kerava, a city that is unique in its challenges and opportunities, demands an in-depth needs assessment to identify the weak areas and determine the best technological solutions. The analysis concentrates on the Kerava community needs especially to seek the most appropriate GeoAI (geospatial AI) and cloud technology that will solve the concerns efficiently.

4.8.1 Needs Assessment for Kerava Municipality

By analyzing the challenges facing the Kerava Municipality, the thesis seeks to identify areas to improve and propose solutions to revolutionize data processing practices. This thesis addresses a comprehensive needs assessment to address critical urban water supply management issues and open different pathways to more efficient and sustainable practices.

4.8.2 Water and Sewage Infrastructure Management

The water supply and sewage network of Kerava demands the incorporation of more advanced technologies in order to optimize the utilization, stop leakages of drinking water and ensure water quality, respectively. The most effective way to satisfy the water needs arising from urban growth and the increasingly complex demand of people is by taking the right management measures on water affairs.

4.8.3 Traffic and Transportation Management

In urban areas like Kerava, traffic jams and transportation issues develop due to ever-increasing urbanization. Improving traffic flow, public transportation systems and infrastructure planning play are crucial factors in achieving mobility and environmental goals.

4.8.4 Environmental Conservation

The natural environment and green spaces are the key aspects that need to be managed to preserve the high quality of life in Kerala. Sustainable land use planning, biodiversity conservation, and climate change countermeasures must be among the priorities in tackling these environmental problems.

4.8.5 Crisis Response and Disaster Control

Besides the crisis response and disaster control plans, the population of Kerava should be protected and provided with security. The use of modern technologies, such as early detection systems, preparedness, and response to natural disasters, along with the coordination of emergency responses, can boost one's ability to handle disasters.

4.9 Evaluation of Suitable GeoAI and Cloud Technologies

The innovative applications of GeoAI and cloud technologies may be helpful in the with respect to the needs of special circumstances in Kerava municipality. By merging geospatial data with those AI algorithms and using cloud computing, nations managing these situations will be able to attain more timely and credible data, have better resource management and make better decisions.

4.9.1 Geospatial Data Analytics

High-tech geospatial software is capable of developing a profile of the Kerava municipality that includes satellite data and aerial images analysis of large spatial data that contains GIS layers. Through machine learning algorithms, geospatial data analysis would give municipal administrations an opportunity to identify similarities, reveal unexpected discrepancies, and utilize all the available information when they are looking for decisions regarding infrastructure planning, environmental management, and urban development.

Using ArcGIS will help the Kerava municipality manage its pipeline network and create detailed 3D models. These models integrate with existing GIS layers. Visualization helps to simulate various scenarios, clearly plan maintenance, as well as real-time monitoring. This facilitates an effective response to infrastructure needs. ArcGIS, with tools for analyzing potential impacts, also supports decision-making for city development and positive environmental impact. The software is also important for the public, as these models will be transparent to residents. This is necessary for community participation in municipal decisions. This approach greatly simplifies the management of the pipeline network, and also makes urban planning and management strategies more convenient.

4.9.2 Remote Sensing Technologies

Conventional remote sensing tools such as LiDAR (Light Detection and Ranging) and UAVs (unmanned drones) generate high-resolution images and topographic data essential for monitoring changes in the physical environment. These sensors provide all the needed information about the Earth's surface. They are essential for analysing modifications in land usage, assessing vegetation health, and identifying hazardous areas, such as areas prone to floods and landslides.
Leica Cyclone 3DR is software used to process large volumes of point cloud data collected via aerial photography and laser scanners, converting this data into detailed 3D models. This functionality shows how efficient it is to create accurate models of pipeline networks. Cyclone 3DR can also transform raw data into detailed 3D images and provide accurate visualizations of pipelines as well as the environment.

The software is integrated with systems such as GIS and CAD (computer aided design). This integration makes data management and analysis easier. The software provides accurate measurements and also highlights potential vulnerabilities. This improves maintenance planning by creating accurate layouts of pipeline infrastructure. This approach is very important for the precise management and modernization of pipeline networks to ensure quality planning and operational safety.

4.9.3 Smart Water Management Systems

Applying intelligent water management systems that rely on GeoAI and cloud-appropriate technologies would be essential for the municipality to manage water distribution, detect leakages, or perform real-time quality monitoring. Municipal officials can utilize sensor networks and IoT devices that are distributed all over the water network to collect data on the flows of water, pressure levels and water quality parameters, which will support the proactive maintenance and the efficient resource allocation.

IoT using 3D modeling in smart water management systems greatly improves the management and control of networks. IoT devices collect data in real time, and this in turn allows you to integrate the data into 3D models. This allows them to be made relevant and dynamic, improving the accuracy of models and providing a basis for decision-making.
The use of IoT allows data to be analyzed, facilitating predictive maintenance and predicting potential failures before they occur for example,to pinpoint leaks and anomalies in flow data. These capabilities reduce downtime and maintenance costs.

IoT makes it easier to visualize the operational status of pipelines and allows for remote monitoring and control of the system, allowing immediate adjustments to the system in response to data from IoT sensors, which is critical to effectively managing complex pipeline networks. Accurate, real-time data for reporting and control is provided through the automation of data collection, as well as its integration into system management processes.

Cybersecurity is needed to effectively integrate these technologies. This is necessary to protect the network and data integrity. It is also important to integrate advanced analytical methods and machine learning. With the help of such integration, the predictive capabilities of the system will significantly improve.

In summary, the integration of IoT with 3D modeling in smart hydrological management systems is the strongest tool to improve the monitoring as well as maintenance of pipeline networks. This approach significantly improves operational efficiency. Of course, another undeniable advantage is the reduction of costs and compliance with environmental standards.

4.9.4 Traffic Flow Optimization

These GeoAI algorithms could scrutinize traffic flow patterns, predict traffic bottlenecks and set optimal timing of traffic signals in order to minimize the ever-present mobility and travel time issues in Kerava. Traffic management systems that have the ability to connect cloud-based platforms to mind real-time data from vehicle sensors, GPS devices and mobile apps can give the power officials in municipalities the ability to develop dynamic routing schemes, congestion pricing measures and optimization for public transportation to manage traffic congestion and provide an efficient transportation network.

Using the existing pipeline network to simplify implementation and optimize traffic flow in Kerava using V2X (Vehicle-to-Everything), Vehicle to Other Vehicle (V2V), Infrastructure (V2I), Pedestrian (V2P), Network (V2N) technologies and cloud (V2C). The installation of communication devices at traffic lights and other elements of road infrastructure will help ensure the protection and invisibility of the system. Such systems can interact with vehicles. Extensive traffic data is collected through network and cloud connections. The gathered data is then analyzed in real-time. This is necessary to control the flow of transport and adjust traffic lights, and this reduces congestion and reduces travel time.
System security and minimization of visual impact, as well as construction disturbances, are ensured by the use of the municipal pipeline network for laying communication and data cables for V2X technologies. The use of artificial intelligence and machine learning algorithms greatly increases and improves the efficiency of real-time traffic management. This makes it possible to predict traffic and quickly respond to various changes, and the integration of pedestrian communications significantly improves pedestrian safety by ensuring safe interactions between vehicles and pedestrians. By optimizing traffic flow in the municipality of Kerava, it improves road safety and also contributes to sustainable development.

4.9.5 Environmental Monitoring and Conservation

GeoAI and cloud technologies enhance environmental monitoring and preservation in Kerava as they visualize and assess spatial data on land cover, vegetation density, air quality and wildlife habitats. Machine learning in algorithms can detect shifts in the environment, reveal ecological hotspots and suggest appropriate conservation interventions by protecting biodiversity and climate change mitigation purposes.

Observation of the environment, as well as its conservation, are very important for maintaining ecosystems. Various technologies are important for this. For example, remote sensing and GIS technologies are needed to monitor deforestation as well as wildlife habitats. Future development should include improved AI integration. This is necessary to quickly detect changes in the environment. Drones required for data collection, as well as automated sensors, are important for collecting data from remote areas. They can be improved using new battery technologies and, of course, autonomous navigation. IoT provides real-time monitoring of air and water quality, with improvements including improved sensor accuracy and expanded networks combined with machine learning to analyze environmental data. This is necessary to predict the consequences of climate change, as well as to optimize resource management.

4.9.6 Emergency Response and Disaster Management

Kerava municipality is given the ability to harmonize a variety of its crisis mitigation procedures in an emergency response platform based on the Cloud. Through the utilization of geospatial data, weather forecasts, and incident reports integrated into one coherent dashboard, emergency respondents have the capability to visualize critical information, analyze risk levels, and deploy resources at the right time during the emergency situations like floods, storms, and wildfires.

In summary, the implementation of a full and effective needs assessment is a must for discovering the key points of interest and threats in the municipal development planning within Kerava municipality. By harnessing the various GeoAI and cloud technologies like geospatial data analytics, remote sensing, smart water management systems, traffic flow optimization, environment monitoring, and emergency response platforms, Kerava would be more capable of meeting its diverse needs and reaching sustainable urban development targets. In combination of Government agencies, Technology providers and other local partners, collaborative effort is crucial for the carrier of these innovative solutions in Kerava, and it will hopefully last in the long term.

In Kerava Municipality, to reduce damage from natural disasters such as snowfall and rain, they can integrate advanced technologies and strategically plan for emergency and disaster management. Multiply early warning systems with sensors need to be implemented. These sensors will detect signs of extreme weather, sending critical alerts to the public, allowing for quick decisions and timely evacuations.

Drainage systems should be modernized, and structures strengthened. This will increase the performance of critical facilities and will also significantly reduce the economic consequences. It is also possible to implement so-called smart flood barriers. This will help upgrade the management of the water system and control the flow of water and prevent flooding. Using GIS will help optimize emergency response by predicting risk areas. It is, of course, important to create educational programs and platforms to prepare residents for disaster scenarios. This will improve security and reduce infrastructure recovery time. By focusing on these strategies, we can significantly reduce the impact of natural disasters in Kerava Municipality, thereby protecting people and infrastructure.

5. METHODOLOGY

5.1 Data Collection and Preparation:

The initial part of a data management and analysis project is vital to the successful outcome of collecting relevant quality, complete, and accurate infrastructure data. The situation is even more critical for the city of Kerava when it is needed to digitalize all data collection and operating processes concerning water and wastewater. This chapter lists out the tools and mechanics revolving the concept of data collection preparation. The first step is to have all the important information about Kerava City's civil infrastructure network. These consist of networks related to roads, pipelines, electrical establishing plantations, and drainage systems Grzegórska et al. (2021). The information collection is concerned with the analysis of pipelines, sewage systems, water distribution networks, treatment plants and pumping stations among others. This process involves a multitude of factors. Broadly, it can be classified into network arrangements, measurements, material specifications, operational parameters, maintenance documentation and data on incidents and repairs in the past.

The site surveys, inspections, and evaluations which could involve multi-sensory equipment such as the Geographic Information System (GIS), Global Positioning System (GPS), distant sensing, and drone surveys might be conducted. This method enables the collection of prompt, precise, and complete data that embraces capturing both visible and invisible things such as ground and above assets (Calzada, 2020). Based on the collected data, the next step involves saving the data on a dedicated server infrastructure to guarantee that it can be accessed, secure, and reliable at any time. Centralized data storage facilitates access in the course of the work of authorized staff since sharing data and maintaining its consistency and accuracy across the departments is a painless task.

The implementation of AWS as the platform for robust data storage is backed by its solidly constructed infrastructure, strong data encryption functionality, many varieties of data backup/recovery options, and the strict enforcement of data security standards and laws. Thus, with the aid of AWS, the organization has the ability to attain data security and robustness, hence this data security and compliance practices of the enterprise will be fulfilled Pohjolainen (2020). The data collection and preliminary preparation phase involves the collection of data related to the constructive assets through Advanced Technologies. The data is later secured and stored in a centralized infrastructure, which is currently Amazon AWS, for instance, where there is security of data and for the data protection to be implemented. These actions are aimed to create a data management, analysis, and decision-making framework that will later lead to establishment of quality data management protocols for the water and sewage company in Kerava city Tuomisto (2023).

5.2 Experimentation with the Keyaqua Platform

The success of the Keyaqua platform in the exploration, analysis and visualization of water sewerage data in the city of Kerava will, to a large extent, depend on the experimentation that will be conducted. The next part focuses on the technique and the techniques employed in the experimental systems that are used for the study. Firstly, initial centralized data transmission occurs through the server to the platform Keyaqua Abokersh et al. (2021). Keyaqua is a dedicated system for analyzing and organizing data, which addresses the issue of web-based connectivity. The software is able to stitch together data, dig into it, impress it with graphical presentation and has the tools needed in decision-making support for infrastructure management. First, the experiment involves feeding data to Keyaqua and then carries out a set of diagnostic tests and examinations to study how the Keyaqua behaves under these circumstances. The aim of these tests is to analyse how Keyaqua can take part in the processes related to infrastructure management, analysis and visualization of information.

Keyaqua's performance consists of three key aspects. First, we need to analyze the ability to improve data processing speed. This is necessary to reduce the processing time of significant amounts of infrastructure data Abokersh et al., (2021). Second, evaluating the reliability and accuracy of Keyaqua's analytical model is essential. To do this, must enable the execution of Keyaqua's algorithms and statistical models, comparing with established patterns and actual events to get an accurate assessment. Third, Keyaqua's visualization capabilities must be evaluated, considering visualization techniques for real-time decision-making Mpuon et al. (2021). The experimental phase of Keyaqua calls for a rigorous measurement of its performance by aligning the criteria against the established industry standards and comparison studies.With the use of a comparative approach, Keaqua's strengths, flaws, and areas for improvement can be highlighted. On top of that, user feedback and usability testing are going to be a vital part of the experimentation process as well Mpuon, Jimudi, and Dzaguma (2021). The users and core players of Keyaqua will comment and suggest therefore helping in learning how easy it is to use, the functionality, and the main purpose. The border of this research is summed up via information compilation on the transfer of infrastructure data, performance assessment of Keyaqua processing data, analyses, and visualization, executing comparative analysis, and collecting feedback from the users. Such operations are conducted to understand whether Keyaqua is indeed contributing to effective decision-making and resource allocation, as well as the databases administrations for the water and sewage network in Kerava City.

5.3 Security Testing with Amazon AWS

5.3.1 Security testing on Amazon AWS

Security testing on Amazon AWS is a very important step to take security measures for water and sewage system of Kerava City. The principal reason for this trial stage is to find out if the data stored in AWS is vulnerable or it is not and if it is protected against cyber threats Osemwowa, et al.(2021). The first stage of the security of the test process is carrying out an overall audit of data infrastructure systems to identify security vulnerabilities. The aim of this evaluation is to discover a break in where robbers can get in and weak spots in the locking system. Furthermore, if the exploration is completed well, you may find domains that necessitate fast resolutions coupled with suitable actions Kaisko (2022). This evaluation aims to determine if the AWS security controls are actually effective and to give an answer to the question of whether the AWS infrastructure leaves any vulnerabilities or not. The simulated vulnerable point scenarios allow for collecting interactive required data on the current assets' vulnerability level and the places for potential risk reduction.

Threat modelling constitutes one of the key components of the security testing process in which one applies models that characterize threats of the production data in AWS platform, as illustrated in the provided picture (Figure 7). This is a process of creative problem-solving that involves identifying new tools, scenarios, and risk factors during data security that will divert them at the time of an attack. The team's full understanding of various risks and hazards, in turn, makes it possible to develop a competent security plan by designing and implementing the measures directed for the elimination of potential threats Kaisko (2022). Apart from the core work of security testing is the verifying of services compliance with the industry-defined standards and data security legislation. It is an ISO standard which is concerned with assessing the company's level of compliance with the regulations, such as SOC 2, GDPR, and data privacy rules.
Ensuring compliance is one of the most important factors in remaining secure and in understanding that if you care about the hardships of critical infrastructure, their data should be the top concern. Amazon AWS (AWS) has acquired powerful security infrastructure and processes from full-scale security testing Gupta (2020). There are many built-in security procedures such as data encryption

for both stored and in-transit, exact access restrictions, network security configurations, activity tracking and logging and hacking mitigation plans are among them Wilenius (2022). As a collective they are employed for cybersecurity purposes and help to ensure data from infrastructure is not compromised by hackers while simultaneously ensuring the integrity, availability, and confidentiality of the data. The security of water and wastewater network infrastructure in Kerava City is strengthened by the adoption of comprehensive security testing as well as the use of top quality protection measures; the risks of security threats like data breaches are reduced.

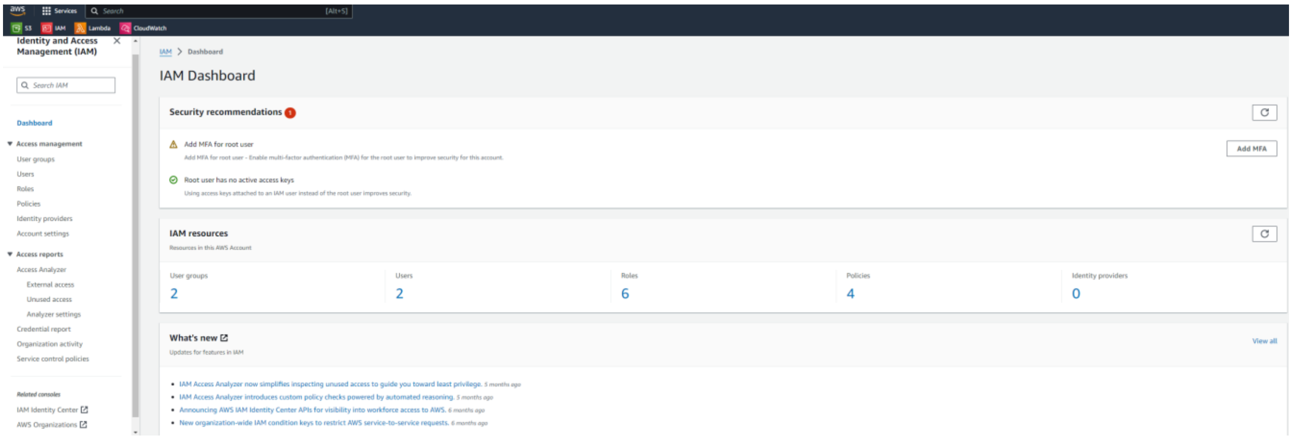

Figure 7 AWS IAM Management

5.3.2 Developing Cloud-Based Geospatial Pipeline for 3D Modeling and Visualization

The development of advanced tools for spatial analysis and visualization is necessary due to the increasing complexity of urban infrastructure. This requires setting up and deploying a cloud geospatial pipeline. Cloud services such as AWS and ArcGIS Pro are used to convert 2D pipeline data into 3D models. It uses the power of GIS software as well as the scalability of cloud computing to improve decision-making processes, especially important in infrastructure management and urban planning. Campiani, McAvoy, Lercari, Stuardo, Delgado, Mejía,Kuester (2023).

The processing and visualization of spatial data has been greatly influenced by the integration of GIS with cloud computing. This integration makes it easier to create more interactive as well as accurate 3D models. Their advantages are very important in many applications. This includes urban planning management as well as infrastructure monitoring.

The cloud pipeline transforms 2D pipeline data into detailed 3D models. Additionally, it includes specific targets for accuracy and functionality.AWS Cloud processes large volumes of geospatial data with scalability and reliability. ArcGIS Pro and its GIS capabilities with deep learning tools are used to accurately create 3D models. Automate a process within a pipeline to improve data throughput and reduce manual intervention.Existing 2D GIS data of city pipelines must be used to collect and store data. They must include all possible geographic coordinates and structural attributes.

Setting up AWS S3 storage includes setting up an S3 bucket, as illustrated in the provided picture (Figure 8). This is needed to systematically store raw 2D data and processed 3D models. This ensures data integrity and, of course, its availability. Data is processed using AWS Lambda. To do this, you need to develop and deploy all AWS Lambda functions. This is needed to automate data preprocessing: converting formats that are triggered by new data. This data is uploaded to S3 buckets.

For 3D modeling with ArcGIS Pro, you should create automated scripts using ArcPy, the Python library for ArcGIS Pro. This is needed to process and convert 2D data into 3D models. These scripts initiate GIS processing tasks and also manage the flow of data between AWS and ArcGIS. Using cloud computing greatly reduces data processing time, and ArcGIS Pro's GIS features improve the detail and accuracy of 3D models. The integration of deep learning, in turn, improves the ability to recognize objects, and this is very important for accurate urban planning.

The cloud-based geospatial pipeline describes in this thesis demonstrates improvements and efficiency in converting 2D pipeline data into 3D models. Such a system supports scalable and efficient data processing and improves analytical capabilities, helping city planners and infrastructure people by providing detailed and accurate 3D visualizations.

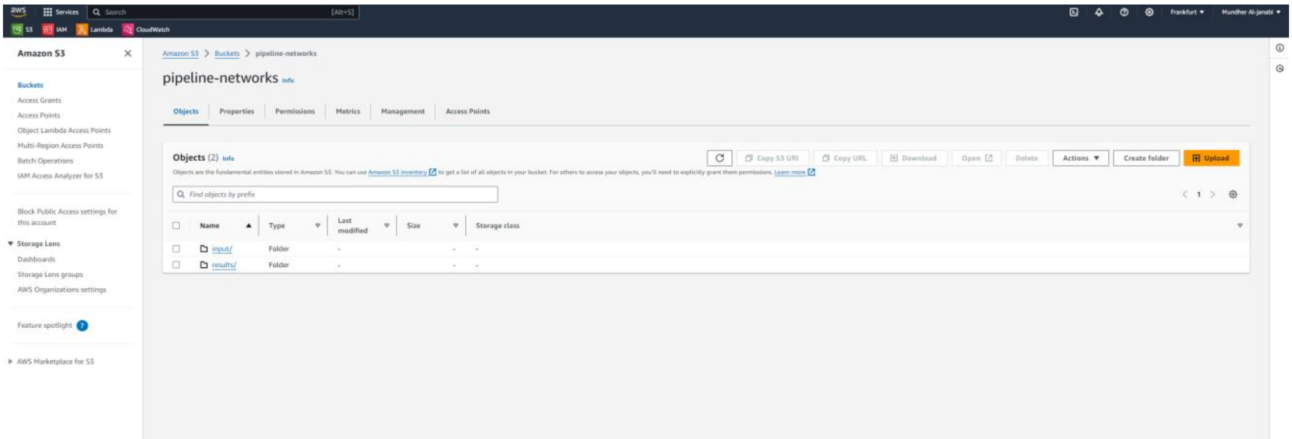

Figure 8 WS S3 Bucket Management

5.4 Integration with Infrakit Platform

The introduction of the Infrakit system is an important milestone further that leads to the management of data including the visualization of the water and sewage network infrastructure in the city of Kerava. The integration requires a collective work to take an advantage of the strengths of Infrakit and the data skills of Keyaqua, with more focus on precise analytics and visualizations of the infrastructure data Salmensuu (2021). The integration process starts with good communication within the platform infrastructure team to accommodate the connection into the Infrakit system with proper strategies for the data feed from Keyaqua to Infrakit. The cooperative work guarantees effective joining of the Keyaqua information extracted and simulated Infrakit for additional analysis and visualization.

A validation and testing of Infrakit having adapted with measurements in the 3D modeling and simulation integrated with Kerava key data including the urban infrastructure is an important part of the integration efforts, as illustrated in the provided picture (Figure 9). This research is to determine if Infrakit can handle the complexities of dealing with network data, render the environmental factors properly that may impact infrastructure and provide simple visualisation tools to aid in better comprehension of the data Calzada (2020). As well, the intense assessment that is made to integrate Infrakit during the installation phase is geared to decide if Infrakit is the best tool for the replication and the simulation of operating pipelines distributed over a country. The reliability and correctness of the modeled outputs are ensured by a set of factors, such as network complexity, simulation accuracy, and the ability to ground the model in given environmental features Jia et al. (2021).
Moreover, a study of User acceptance of 3D modeling function and visualization features of InfraKit is evaluated to determine its applicability in the practical world of construction and construction processes decision-making. The fundamental reason for the introduction of the Infrakit integration is the digitalization of data by incorporating the simulation and modelling of CHMC in data management. This aims to reach much further into the behavior of members of the infrastructure, to make environmental impacts closer, to support the infrastructure management and planning of the city of Kerava better Abokersh et al (2021). The purpose of this process is to offer the best results of the management and visualization of the information that is related to the water and wastewater networks. This assessment shall be based on the close cooperation with Infrakit. The objective is that people have something that will enrich them and help in the best possible way to manage the resources.

Figure 9 Infrakit 3D Pipeline Mapping infrakit.fi

5.5 Performance Evaluation and User Acceptance

The assessment of the system, which is Infrakit's 3D modeling abilities and data from Keyaqua, will be carried out at the project analysis and user acceptance period. The current phase encompasses two primary components: the assessment of both technical performance and users and stakeholders cooperating to provide feedback regarding their acceptance and satisfaction with the Infrakit 3D Modeling System Grzegórska et al., (2021). The initial stage will entail examining the performance of Infrakit in aspects of 3D modelling and construction. The goal of this thesis is to compare the time efficiency, accuracy, and ease of use between Infrakit and Keyaqua when modeling water and/or sewage networks in Kerava City by Pohjolainen (2020). The crucial performance indices are the degree of accuracy and speed of 3D modeling, the system capabilities for dealing with huge data sets, and the quality of the visuals created in Infrakit, as illustrated in the provided picture (Figure 10). The integrated system is appraised by gathering users', stakeholders', and domain experts' views and through this evaluation ascertain the satisfaction and the acceptance levels Tuomisto (2023). This aspect of user acceptability testing includes the collection of relevant information, which refers to usability, intuitiveness and the general user experience when they use integrated platform.

Stakeholders' feedback at this stage is the most valuable source in the study of different needs, assessment of improvement areas, and guaranteeing the system's alignment with their desires and aspirations. The feedback and insights acquired are commonly operated on within the improvement process that runs on iterations, and we use real-world usage scenarios to produce better system functionality and usability through their analyses Mpuon et al. (2021). The iterative approach embodies the process of iterating over the user interface, improving performance, resolving usability issues, and integrating additional features or functionalities based on stakeholder feedback. The project guarantees that the integrated system complies with technical performance standards and meets users' expectations Abokersh et al. (2021). This way, the water and sewage network in Kerava City becomes more efficient in decision-making and resource management due to the active participation of the user, stakeholders, and domain experts in the evaluation and improvement process.

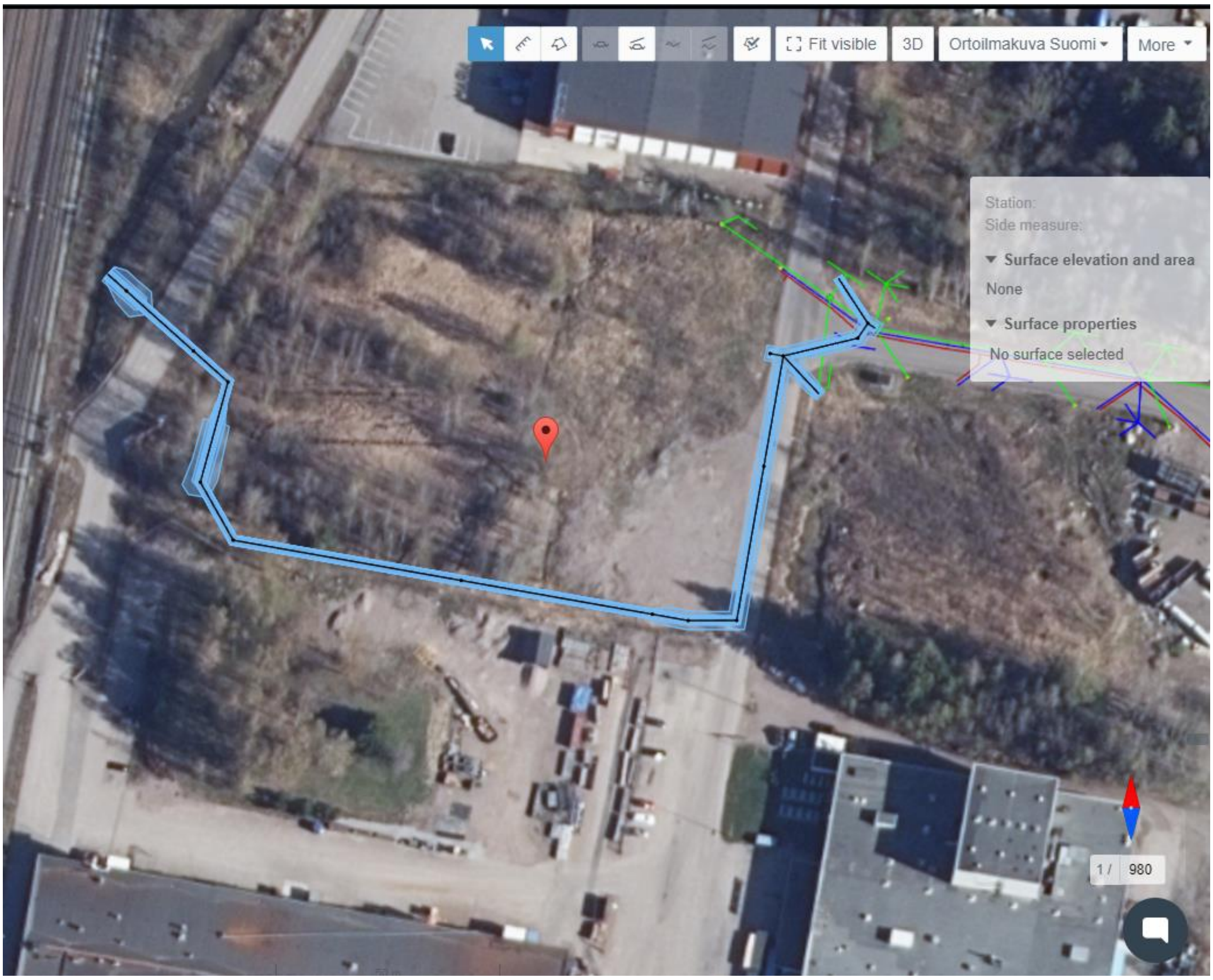

Figure 10 Infrakit 3D Pipeline Mapping Kerava infrakit.fi

5.6 Ethical Considerations

Data management and infrastructure optimization, in their perusal, require covering a lot of ethical aspects to secure integrity, fairness, and the security of all the stakeholders. On top of the ethical considerations is the safeguarding of sensitive data and the guarantee of following the law and ethical norms throughout the process of data collection, storage, and analysis Mpuon et al. (2021). One of the issues to be addressed is informed consent from subjects, especially when dealing with sensitive data such as urban infrastructure and systems networks. Other than fairness and impartiality for all stakeholders, such as urban dwellers, professionals, and technology manufacturers, is another ethical issue that must be considered. Sources of bias and conflict of interest need to be minimized as they could affect both the study results and decision-making processes.

Moreover, researchers need to be totally reliable and accountable at every phase of the study process, from information collection to the publication of the outcome of the research. However, the reproducibility and validity of outcomes may not happen if the procedures, data sources, and analysis techniques are not fully documented Wilenius (2022). Ethical considerations also include the conscious use of those technological platforms and tools to manage data. Researchers should pay attention to data security protocols, use data anonymization when required, and fulfill data governance principles in order to protect people's privacy and confidentiality Osemwowa et al.(2021). This data safeguarding, stakeholder engagement and transparency, accountability, and responsible use of technology, in general, is about the ethical side of the research approach. Such considerations are needed to maintain the ethical standards of the study and the integrity of the results.

This methodology is a systematic way of collecting data, doing experiments, penetration testing, integrating systems, and assessing performance. The prime purpose is to make a switch to modern data management systems for the water and sewage company in Kerava. The initiative aims to achieve data handling efficiency, effective allocation of resources, and informed decision-making for sustainable infrastructure management through the implementation of KEYAQUA and Infrakit, which are advanced platforms, and the application of robust security entitlements and user-centric evaluation.

5.7 Through Advanced Data Integration and Analysis by Keyaqua

Playing a critical role in the successful implementation of various projects, Keyaqua was developed to effectively manage water and wastewater systems. The importance of this program is to centrally manage data. This approach is needed to ensure consistency and accuracy of information. The benefit of Keyaqua is that critical data is available to all stakeholders, which greatly helps to maintain compliance with stringent environmental regulations. This is also extremely important to avoid legal problems.

Keyaqua collects data through integration with sensor technologies, as well as sensors and IoT installed in pipelines. This is needed to monitor water flow in real time, as well as monitor pressure, quality and integrity of pipelines. This approach allows any discrepancies to be identified immediately, and GIS compatibility greatly improves data management and visualization. Keypro. (n.d.)

The program contains powerful data analysis and reporting tools. They can process large amounts of data and predict potential problems and generate detailed reports. Such tools are an integral part of proactive management that prevent problems before they worsen. Keyaqua has a user-friendly interface that makes data entry, retrieval, reporting, and reporting easy and accessible to all team members with varying levels of technical expertise. The program is suitable for projects of various sizes, from small to large-scale municipal networks.

By using Keyaqua, Kerawa ensures that their water management projects are successfully implemented and are sustainable and meet regulatory standards, resulting in more efficient and reliable water infrastructure systems.

5.8 Results

The goal of the project was to establish an integrated system for Kerava's water and sewer network, the main feature of which is the integration of In-frakit's capabilities. The project allowed us to have four main components, which were - data management, GIS Pro integration, use of cloud resources and deep learning application.

5.8.1 ArcGIS Pro Integration

The application of ArcGIS Pro into the research system was a consequential event triggering the development in wasted water and sewage system management in Kerava. Using this powerful technology led the project to a significant level of progress as it successfully implemented 2D pipeline data into full-detailed 3D models and thus brought the visualization of the municipal infrastructure to a new level of comprehension. The utilization of Buffer icon in ArcGIS Pro is the center of this exercise. This intricate tool made it possible to process the initial linear pipeline data into cylindrical features full of precision and fidelity that users have not seen before. With the careful use of the Buffer 3D feature, the static drawings were transformed into living models that could be clearly seen by the various stakeholders thanks to this function, as illustrated in the provided picture (Figure 11). As well as that, modification altitude assumed the key function in reaching the highest accuracy of the 3D models.

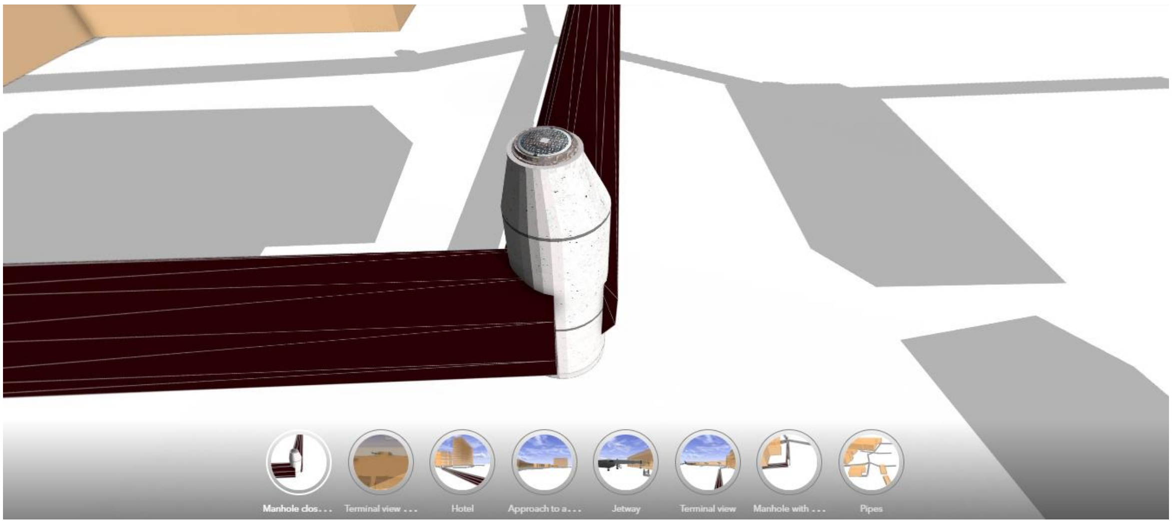

Figure 11 ArcGIS Pro 3D Pipeline Modeling Hussein, Mahdi, & Al-Shukri, (2023)

Precision elevation settings were carefully adjusted by all team members to get an accurate snapshot of the infrastructure topology, even though navigation was under the ground. Addressing the necessity of experts' aforementioned capability, this capability was proved invaluable in fostering a nuanced understanding of the spatial layout and interconnectivity of the water and sewage network, which the stakeholders used as the leverage for informed decision-making of effective management. The integration of advanced 3D modeling capabilities of ArcGIS Pro not just revolutionized the visualization of water and sewage network, but also provided the platform for more insightful strategic planning and efficient infrastructure management at Kerava. By overcoming the restraints imposed on normally known 2-Dimensional systems, it allowed for new avenues of innovation and optimization in the management of urban infrastructure. Also, the remarkable detail of raising and lowering positions meant the 3D models were an accurate representation of the municipal complexities including underground features, as illustrated in the provided picture (Figure 12). It not only improved the visual quality of models being made as well as informed decisions related to infrastructure repair, reconstruction and expansion through more detailed level of detail.

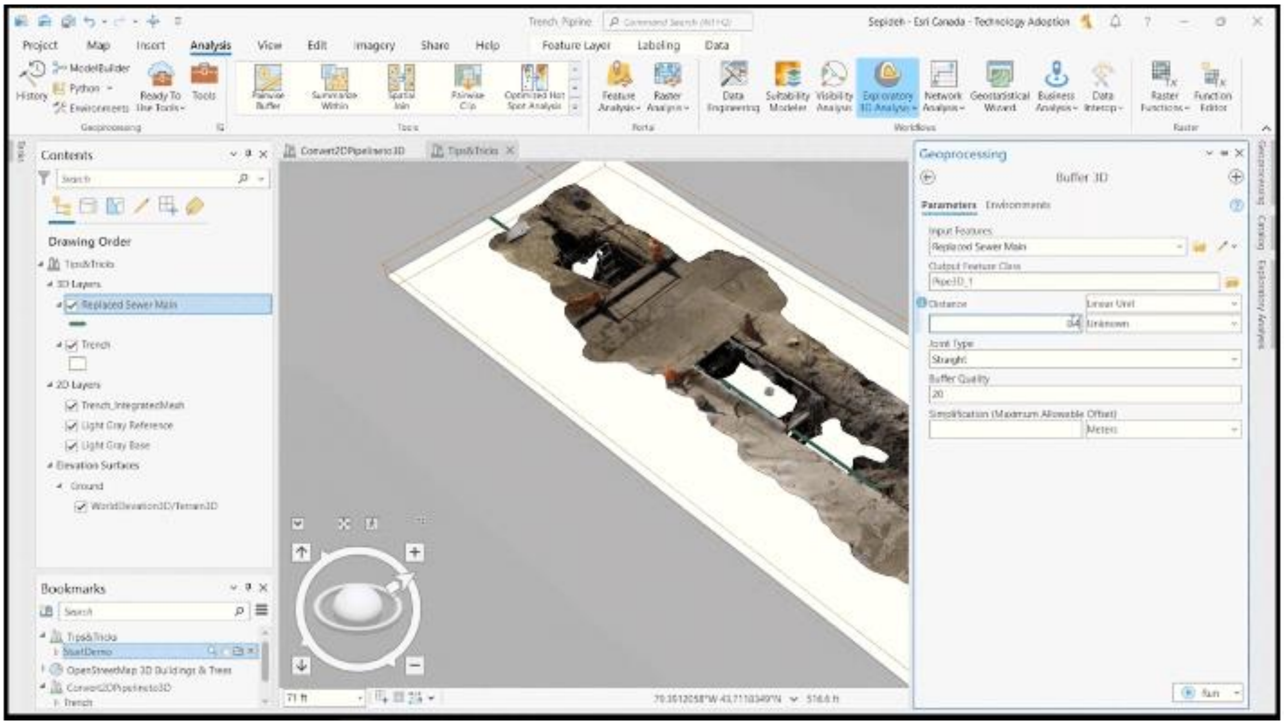

Figure 12 ArcGIS Pro Geoprocessing for 3D Modelling Corbin, (2020)

5.8.2 Infrakit Integration

Infrakit ,the data collection, analysis and management tool, which is the core of the change being brought to infrastructure network management for the city of Kerava, as illustrated in the provided picture (Figure 13). With its professional tools Infrakit provides a unique platform to deal with the most complex aspects of infrastructure data in a time- and cost-effective manner, introducing a new paradigm of implementation efficiency and informed management. The integration of ArcGIS Pro signifies the watershed moment of how infrastructure management practices have been regarded in the past.

Figure 13 Infrakit and ArcGIS Pro Integration for Infrastructure Management Corbin (2020).

Through this symbiosis between Infrakit and ArcGIS Pro, transfer of 3D models and spatial data into the Infrakit ecosystem is smooth and efficient. These powerful platforms bridging the gap gives stakeholders with holistic and unified infrastructure picture. The platforms act as a single entity. The application of 3D modeling and GIS pro power with Infrakit full data management capacity leads to the creation of a well-organized depot of roads repair information in detail. This integration does not only increase the fidelity and accuracy of data but also makes real-time collaboration and analysis possible, providing stakeholders with data-driven alternatives that they can trust, as illustrated in the provided picture (Figure 14).

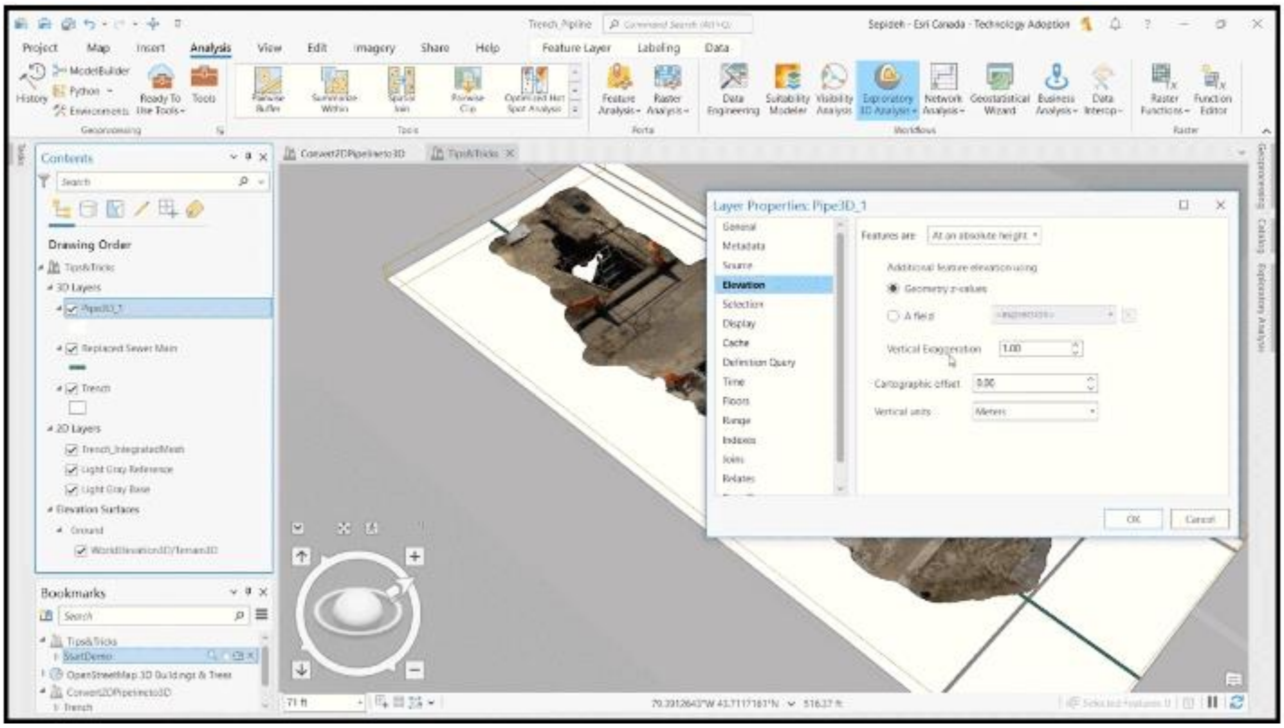

Figure 14 Seamless 3D Model Transfer between ArcGIS Pro and Infrakit Sugianto, Hosea, Jabar, Irwansyah & Fitrianah, (2023)

Moreover, with the KeyAqua data integration, which is predominantly used with infrastructure, this greatly enhances the Infrakit ecosystem. Through the amalgamation of information from different channels one integrated network, stakeholders are enabled to have knowledge of the infrastructure network. This data aggregation equips all key parties with the necessary data necessary to make data-driven choice and devise strategic plans that will deliver efficiency and resilience in infrastructure management. The unified perspective that InfraKit affords through its integration capabilities surpasses organizational borders, supporting sharing and cooperation by the stakeholders. By creating one data hub which enables data sharing and analysis, Infrakit helps to set apart the lines of demarcation and bring all the players together for common goals. It is no longer just about delegating responsibilities and monitoring results, but instead, it is about working together to improve efficiency, with the idea of driving innovation, creativity and ultimately, improvement in the practices of infrastructure management. Furthermore, Infrakit broadens data management ranging from the simple aggregation and storage of data. Advanced technology of its simulation models lays a basis for the stakeholders to run various simulations on events and determine outcomes, this helps in proactive decision-making and risk management. Simulating different scenarios allows stakeholders to discover any hazards and opportunities, subsequently, avoiding risks and improving resource management.

Infrakit's graphical capabilities and advanced image processing provide the backdrop for data management. With Infrakit's user-friendly and interactive visualizations of infrastructure data, stakeholders are able to better understand and analyze the network's performance and operational status. The visualizations not only make the more frequent but other functions such as sharing the information and making common understanding of the multi-dimensional infrastructure problems, As illustrated in the provided picture (Figure 15). Finally, bringing Infrakit as part of the infrastructure management of Kerava signifies an important achievement in the way of achieving efficient and effective infrastructure management. Infrakit’s robust data management capabilities along with its integration with GIS platforms like ArcGIS Pro offers stakeholders the rights tools and insights trusted to navigate complex terrain of Infrastructure management with vision and confidence. Being the key player in the infrastructure management of the municipality, Infrakit’s role cannot be over-emphasized as it holds the future of the municipality in the palm of its hands. Efficiency, resilience, and sustainability are the watchwords for its operation.

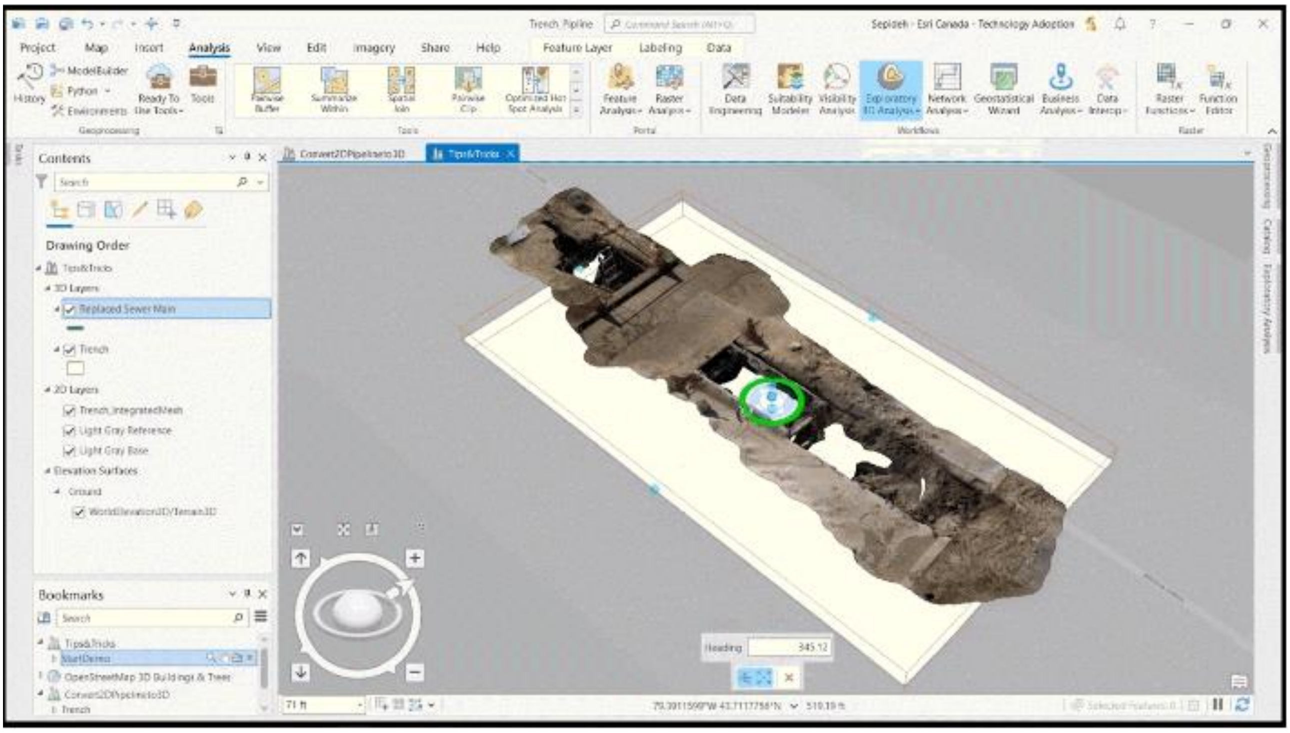

Figure 15 Enhanced Data Integration with KeyAqua and Infrakit Sugianto, Hosea, Jabar, Irwansyah & Fitrianah, (2023)

5.8.3 Cloud Computing and Deep Learning:

In the era of digital technologies and data surge, data management and utilization are the essential features of business operations in different sectors. In the field of urban infrastructure management, the integration of cloud computing and deep leaning methods has brought about new dynamism resulting in Kerava municipality's ability to use data for improved decision-making, prediction, and proactive intervention. S3 buckets in AWS are of core significance in this emerging terrain, tailor made to store the voluminous data that is produced and processed during the different lifecycle phases. The buckets have some important features such as scalability, durability, and accessibility that enable them to provide an agile and reliable storage solution for water and sewage network management. The most relevant data entries to these buckets no longer remain associated purely with static resources but become sources for proactive research, data mining, prognosis, and prediction. At the very foundation of the strong regulatory role of cloud computing is the setup of effective user role management and access permissions masterfully control through AWS IAM (Identity and Access Management). In the context of the urban infrastructure management project where data safety and confidentiality is the key, IAM focus on ensuring proper data access and utilization which are vital in maintaining security. Defining an authority scope provides the municipality with granular level of access policies and roles, thus controlling it precisely and accordingly stops unauthorized use or breach. These reinforced security ecosystems enhance the level of trust of all stakeholders, underpin an accommodating atmosphere for collective data-driven decision making. The era of AI based on deep learning technologies comes into being where this feature is paramount for thorough a data understanding. Through the power of neural network architecture, deep learning algorithms can cover massive data sets and detect those patterns, correlations and abnormalities which escape traditional analyzing methods.

Machine learning techniques used in the domain of water and sewage networks are vital as they work to channel pre-dictive analytics that allow municipalities to foresee system failures, anticipate maintenance needs, and control the local water and sewage network system, as illustrated in the provided picture (Figure 16). Deep learning allows to augment reactive with favourable preventive measures, strengthening resilience for urban networks and reducing risks during the time of their operation. Deep learning extends predictive analytics, which is used in diverse segments of structure management. For instance, image recognition algorithms analyze data from sensor networks or surveillance cameras, detecting leaks, blockages, or structural abnormalities in real-time. As opposed to the analytical methods that are used in NLP, textual data is parsed from maintenance logs, customer feedback, or regulatory reports to draw out useful insights in order to provide trends. This multi-modal strategy gives urban infrastructure management a realization of the interdependency of the complex systems which improves the quality of decision-making and resource allocation. The selective utilization of on-demand cloud computing further deep learning performance and scale that are truly worthwhile. Platforms like Amazon SageMaker that are based on cloud give a full-course software infrastructure allowing engineers to develop, educate and send models at the scale. Municipalities can harness elastic computer resources to accelerate model training cycles, deal with dynamic process loads, and respond to growing data needs by utilizing compute resources. Furthermore, cloud-based infrastructures facilitate teamwork and knowledge transfer, allowing municipalities to capitalize on prevailing frameworks, learning materials, and models by a flourishing community of developers and researchers. The alliance between cloud computing and deep learning is not only restricted to infrastructure management, but also penetrates broader fields like biodiversity monitoring, energy management, and public safety. Over every one of the areas, the blending of these technologies acts as a key in opening the way for innovation, resilience, and sustainability to drive the new paradigm of data-powered governance and urban development.

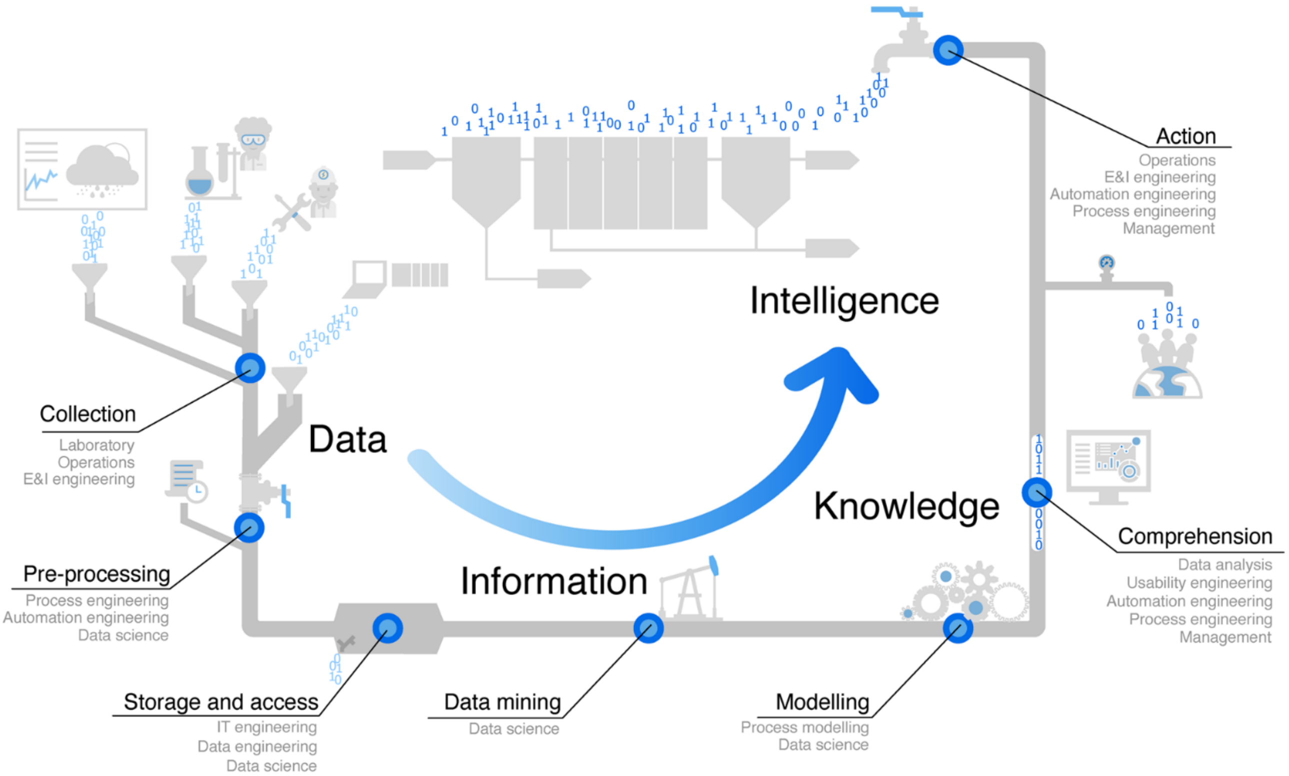

Figure 16 information handling, digital transformation, virtual twin, data attributes and sewage water modelling Nicolaï, Vanrolleghem, (2020).

5.8.4 Operational Efficiency

The use of ArcGIS Pro, Infrakit, and cloud computing solutions has resulted in significant innovation in operational efficiency in water and sewage system of Kerava. Through optimization of such modern technologies, many processes that were quite laborious and time-consuming were automated and facilitated, which positively affected performance, as illustrated in the provided picture (Figure 17). Among the most notable examples of operational efficiency growth is the speed of data collection, analysis and decision-making process. GIS Pro platform serves as a effective tool for location analysis and illustration which allows stakeholders to dwell on data and make efficient conclusions with speed.

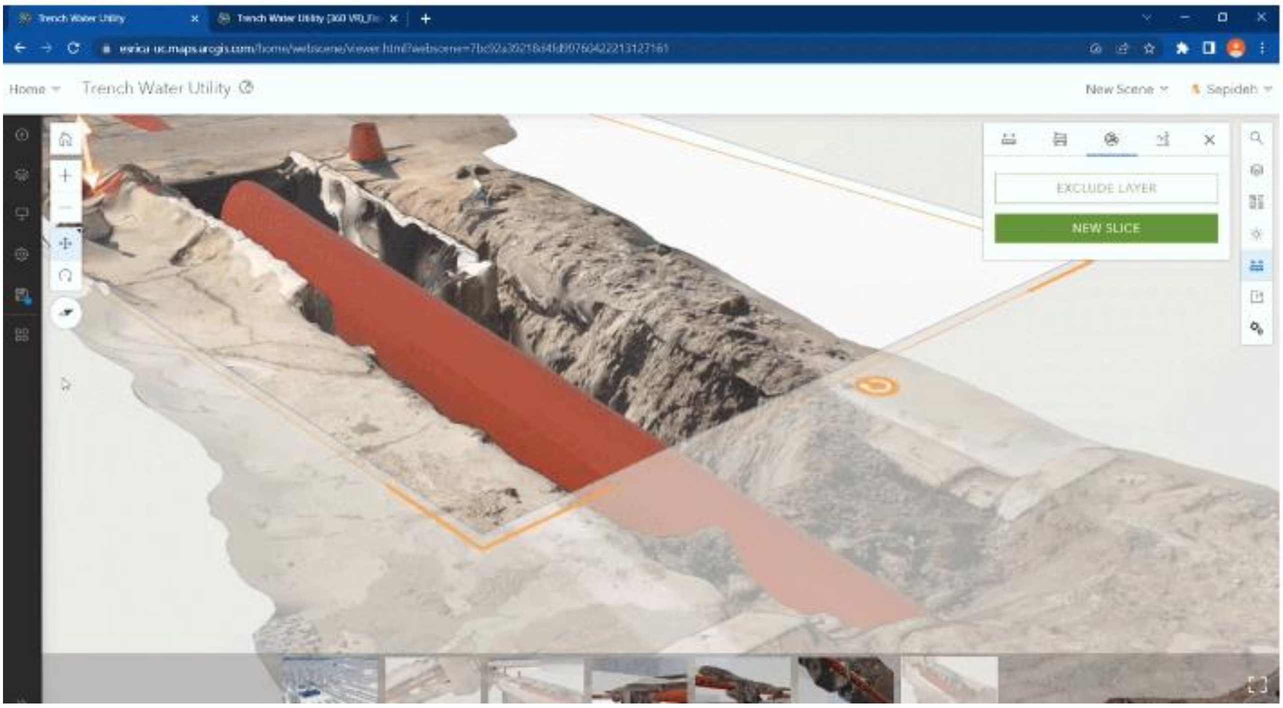

Figure 17 Optimized Data Processing with ArcGIS Pro, Infrakit, and Cloud Solutions Kanerva, (2024)

A more integrated operation with Infrakit including a centralized shared platform for data management and simulation contributes to these functions. Automation can be done more effective than before, with the corresponding cloud computing solutions now providing the ability to process and analyze such tasks quickly and precisely. Cloud-based data storage solutions like AWS S3 bucket have facilitated wide access to the large volume of information, enabling the stakeholders to catch-up with data swiftly to make informed decision. The automation, for instance, implementing S3 events, and lambda functions also shows that there is the potential for further automation and process optimization in operations. Data files collected and generated through data collection activities can be directly transferred into designated S3 bucket folders that will then trigger data processing and analysis tasks without human intervention. To sum up, the symbiosis of ArcGIS Pro, Infrakit and cloud computing resources in the water and sewage utility management system of Kerava contributed to the total system modernization of the latter. The duties that were once manual and time-consuming to perform can now be carried out with higher speeds, precision and automation reducing, therefore, time spent on the tasks and improving employee efficiency.

6 DISCUSSION

The results analysis of the integration of different technologies and methodologies used to address the water and sewage network management challenges in the urban environment is focused, specifically on the city of Kerava. The resulting analysis is followed by the discussed implications that will emphasise the findings' meaning, the scope of the limitations, and directions for future work.

6.1 Integration of ArcGIS Pro and Infrakit

The use of both ArcGIS Pro and Infrakit is a significant step forward in the management of water and sewage networks in municipal environment, especially for the city of Kerava. Such integration has turned out to be a decisive factor in developing visualization, analysis, and management by giving stakeholders a broader perception of the infrastructure and simplify data processing. ArcGIS Pro, a GIS software with robust capabilities for spatial analysis, data visualization, and management. The unique capability of this system is to reveal 2D pipe data in 3D model form for multiple contexts, which allows decision-makers to comprehend the integrated infrastructure in three dimensions. This function is most beneficial for the systems where knowing the spatial dependency of the different components is a key element in effective management: water and sewage networks, for example. Using ArcGIS Pro's 3D modelling capabilities, the counterparties in Kerava received the required infor-mation about the layout of the network and the locations where there were points collapsed into one line. For example, engineers can use ArcGIS Pro to detect all the utility pipes under the ground, see how they are spatially related to other utilities or natural features around them. This capacity allowed them to determine the critical zones and develop the exact maintenance or interventions strategies in the next step.

Similarly, the seamless transfer of 3D models and spatial data from ArcGIS Pro to Infrakit not only enabled a centralized platform for documenting, replicating and data governance of a certain infrastructure but also facilitated their construction, design and analysis. As a multi-faceted infrastructure management tool, Infrakit is equipped with collaborative features that allow users from different departments or organizations to gain access to the information and process the data. This integration enabled the organisations to reduce operational costs, improve the co-ordination and enhance the networking through provision of a unified view of infrastructures. The characteristic of Infrakit's teamwork, which promotes sharing and collaboration, assisted the involved parties in working together effectively to accomplish their common objectives. For example, operation, maintenance, and engineering staff would coordinate workflow on infrastructure projects. They would share knowledge and expertise to improve maintenance activities decision-making.

6.2 Utilization of Cloud Computing and Deep Learning

The use of cloud resources and deep learning enabled data handling and analytics contribute largely to the project. The project used the astonishing storage capabilities of AWS S3 buckets to provide for the large amount of data stored and used during the course of the project. The agility of cloud computing had facilitated the processing and analysis of data in an efficient manner, which led to tasks like predictive maintenance and detection of anomalies. Unlike traditional risk assessment, deep learning techniques enable the extraction of value from the data, such as predicting potential failures in the water and sewage network based on historical data. Through using the cloud’s training and deployment of deep learning models, stakeholders can effectively address infrastructural problems. At the same time, applying these methods exposed problems like data quality issues, the complexity of algorithms, and the need for more computational resources. Overcoming these limitations would become a key factor in developing models which will be a key role in maintaining their application for real-world applications.

6.3 Operational Efficiency and Automation

Cloud computing resource utilisation with deep learning techniques have changed water and sewerage networks' data-handling and analysis processes. AWS S3 buckets are becoming a fundamental resource to which a versatile and reliable proportion of data can be moved, preserving it. Few other storage solutions can beat the flexibility of the cloud, which allows for storing, accessing, and managing any kind of data of any size or complexity. AWS S3 opens the data can be shared from anywhere where internet connection is available and the enterprise level collaboration becomes an ordinary fact for the stakeholders of the project. Moreover, the adaptability of cloud computing does not stop with storage but covers data processing and analysis as well. There is a variety of tools and services that are offered by AWS cloud computing platforms, and it simplifies work streams associated with data processing. These tasks include predictive maintenance and anomaly detection. Through the exploitation of cloud-based resources for data analytics, stakeholders can leverage scalable computing resources for efficient handling of data-intensive complex tasks. This attribute enables users to uncover crucial insights from their data that prompts effective policy and management measures across the water and sewage network.

Data analysis methods, like deep learning techniques, such as neural networks, constitute a hot technology that covers water and sewage network management with promising results. These data-derived techniques will not only provide insights from large and complex networks but also predict a possible failure in the whole system by processing historical data record. Even though deep learning methods could be considered as the most recent innovation in machine learning, the implementation of this technique also has its challenges. On the top of the list of challenges relating to data quality is the issue of data quality that may jeopardize the accuracy of predictive models a great deal. Predictive models depend on the accuracy and reliability of information inputs, therefore, in deep learning the pattern recognition, ensuring the data inputs quality and consistency is critical. Moreover, the inconsistency of deep learning algorithms complexity and the large volume of the computational resources for training and deployment of these models are the main problems for the stakeholders. The problem-solving processes have to be very cautious and involve data auditing, algorithm optimization and proper resource allocation.

6.4 Limitations and Future Directions:

In spite of the substantial accomplishments that have been achieved so far, several limitations and areas for further improvement should be considered. For example, the scalability and cost-effectiveness of cloud computing solutions must be done cautiously, and especially as the volume of information keep increasing. Besides that, there is still a need to have deep learning techniques such as prediction models to be proved true and to be relied on through strict tests and validation processes. In this case, researchers, engineers, and experts from the relevant fields jointly need to have the ability to improve the models to an ever-greater extent in the future.

In addition, the consolidation of ArcGIS Pro and Infrakit could take the next step through real-time data streams and sensor data feeds to provide proactive monitoring and management of the foundation. Continual funding for research and developments together with consistent collaborative efforts with sector stakeholders shall be indispensable for innovation drive and handling emerging challenges in water and sewage management.

Finally, the research findings show that the use of developed technologies and methods can improve upon the management of water networks. Using ArcGIS Pro, Infrakit, cloud computing and deep learning technologies stakeholders are able to make operational efficiency, take optimum safety decisions reduce risks and maintain the resilience and sustainability of the systems.

7 CONCLUSION

Finally, the thesis has explicated the complex strategy of water and sewage system operation in urban environments by drawing an example of Kera-va municipality. Through utilization of these latest technologies and strategies, such as ArcGIS Pro, Infrakit cloud computing and deep learning, great steps have been translated into the actualization of the infrastructure management challenges in the present day municipalities. The implementation of cloud computing services, especially AWS S3 buckets, provides the capacity that is needed for storage of the data used for the project without errors. This has given various shareholders the ability to store, interface and manage data effectively, the basis for connection, flow of data and sharing amongst them. Moreover, cloud computing has made data processing and analysis more efficient, permitting all stakeholders to uncover useful insights about their data and make data-driven decisions on the direction they should take in terms of effective infrastructure management.

7.1 Improvement of Urban Water Systems by AI and AWS Technologies

Modern algorithms based on the deep learning approach have demonstrated a high competence in data processing, which allows for multi-varied data to be analyzed efficiently. Through accessing trained deep learning models through cloud-based resources such as AWS and leveraging them to predict the trends of the water and sewage network, stakeholders can avoid any leakages or overflow, which is a function of proactive management. Nonetheless, dilemmas to do with data quality, algorithm complexity and computational resources need to be tackled to achieve accuracy and reliability in prediction models. Notwithstanding such barriers, the deployment of innovative technologies have been imperative in enhancing operational efficiency, better decision-making process, and the maintenance of resilient infrastructure. Through data management harmonization, predictive maintenance, and proactive management strategies, shareholders may mitigate risks, optimize resources allocation, and boost network performance in water and sewage line.

In the long run, what follows is persistent financing of the research and development, availing a chance of collaboration with partners in the industry, and being prepared for any innovation that will drive more changes in the water and sewage network management. Through technology solutions, the problems and advantages are addressed. Then the basic infrastructures like water supply and other structures are built upon for a more sustainable and resilient living city. In essence, this thesis proves that technology plays the role of pathfinder on the course towards a greener urban environment full of opportunities.

Companies contracting with the municipality of Kerava did not give consent to the implementation of the proposals that are described in this thesis; in this regard, there may be an option to consider continuing the research since there are many additional resources and to obtain results and increase in financial investments in the project is required. To continue research, it is necessary to present the development so that meets the requirements and expectations of the city authorities.

One option to improve urban water systems is to use modelling and simulation to show the potential productivity of the author’s suggested solutions. This approach can help argue in as much detail as possible for my research and convince the municipal leadership to reconsider their decision. Of course, it is important to actively involve the public in introducing methods through organizing seminars and presentations. This will help increase knowledge about the project's goals and positive societal impact.

REFERENCES

Okwori, E., Pericault, Y., Ugarelli, R., Viklander, M., & Hedström, A. (2021). Data-driven asset management in urban water pipe networks: A proposed conceptual framework. *Journal of Hydroinformatics*, *23*(5), 1014-1029. https://www.sciencedirect.com/science/article/pii/S2352152X21007222

Arnold, C. R. (2023). *Locating Low Head Dams Using a Deep Learning Model in ArcGIS Pro With Aerial Imagery* (Doctoral dissertation, Utah State University). https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=9911&context=etd

Babamiri, A. S., Pishvaee, M. S., & Mirzamohammadi, S. (2020). The analysis of financially sustainable management strategies of urban water distribution network under increasing block tariff structure: A system dynamics approach. *Sustainable Cities and Society*, *60*, 102193. https://www.mdpi.com/2071-1050/13/6/3313

Barton, N. A., Hallett, S. H., & Jude, S. R. (2022). The challenges of predicting pipe failures in clean water networks: a view from current practice. *Water Supply*, *22*(1), 527-541. https://iwaponline.com/ws/article/22/4/3784/86272

Billen, R. (2000). Integration of 3D information in urban GIS: A conceptual view. In *Proceedings of the ISPRS 2000*. https://orbi.uliege.be/bitstream/2268/29975/1/article988.PDF

BOZKURT, C. (2022). Strategic water loss management: Current status and new model for future. https://dergipark.org.tr/en/download/article-file/2469866

Calzada, I. (2020). Replicating smart cities: The city-to-city learning programme in the Replicate EC-H2020-SCC project. *Smart Cities*, *3*(3), 978-1003. https://www.tandfonline.com/doi/pdf/10.1080/07352166.2021.1994861

Campiani, A., McAvoy, S., Lercari, N., Stuardo, R. L., Delgado, G. J., Mejía, J. L., ... & Kuester, F. (2023). Developing an interoperable cloud-based visualization workflow for 3D archaeological heritage data: The Palenque 3D Archaeological Atlas. *Digital Applications in Archaeology and Cultural Heritage*, *31*, e00293. https://www.sciencedirect.com/science/article/pii/S2212054823000383

Daulat, S., Rokstad, M. M., Klein-Paste, A., Langeveld, J., & Tscheikner-Gratl, F. (2024). Challenges of integrated multi-infrastructure asset management: a review of pavement, sewer, and water distribution networks. *Structure and Infrastructure Engineering*, *20*(4), 546-565. https://www.sciencedirect.com/science/article/pii/S0951832023005252

Dawood, T., Elwakil, E., Novoa, H. M., & Delgado, J. F. G. (2020). Artificial intelligence for the modeling of water pipes deterioration mechanisms. *Automation in Construction*, *120*, 103398.

Du, Y., & Zlatanova, S. (2006). An approach for 3D visualization of pipelines. *Innovations in 3D geo information systems*, 501-517.
https://gdmc.nl/publications/2006/3D_visualization_of_pipelines.pdf

Döllner, J. (2020). Geospatial artificial intelligence: potentials of machine learning for 3D point clouds and geospatial digital twins. *PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science*, *88*(1), 15-24.
https://link.springer.com/content/pdf/10.1007/s41064-020-00102-3.pdf

Du, Y., & Zlatanova, S. (2006). An approach for 3D visualization of pipelines. *Innovations in 3D geo information systems*, 501-517.
https://gdmc.nl/publications/2006/3D_visualization_of_pipelines.pdf

Dutt, S., & Punniakotty, P. (2021). Sustainable Water Management: Smart Solutions for Equity in Vellore Municipal Corporation. In *Sustainable Urban Architecture: Select Proceedings of VALUE 2020* (pp. 67-82). Springer Singapore.
https://www.mdpi.com/2077-0472/13/7/1367

Djahel, S., Doolan, R., Muntean, G. M., & Murphy, J. (2014). A communications-oriented perspective on traffic management systems for smart cities: Challenges and innovative approaches. *IEEE Communications Surveys & Tutorials*, *17*(1), 125-151.
https://e-space.mmu.ac.uk/600549/2/IEEE%20COMST%20Camera%20ready.pdf

Goodchild, M. F. (2000). Communicating geographic information in a digital age.
https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=d73d68ca8c8853a608bfda3ee2ae0a984c664c01

Grzegórska, A., Rybarczyk, P., Lukoševičius, V., Sobczak, J., & Rogala, A. (2021). Smart asset management for district heating systems in the Baltic Sea Region. *Energies*, *14*(2), 314.
https://www.sciencedirect.com/science/article/pii/S2352484722014275

Gupta, A. D., Pandey, P., Feijóo, A., Yaseen, Z. M., & Bokde, N. D. (2020). Smart water technology for efficient water resource management: A review. *Energies*, *13*(23), 6268.
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9999442

Jia, Y., Zheng, F., Maier, H. R., Ostfeld, A., Creaco, E., Savic, D., ... & Kapelan, Z. (2021). Water quality modeling in sewer networks: Review and future research directions. *Water Research*, *202*, 117419. https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2021WR031808

Johnson, L. B. (1990). Analyzing spatial and temporal phenomena using geographical information systems: a review of ecological applications. *Landscape Ecology*, *4*, 31-43.

Joseph, K., Sharma, A. K., & van Staden, R. (2022). Development of an Intelligent Urban Water Network System. Water 2022, 14, 1320.
https://www.mdpi.com/2073-4441/14/9/1320

Kaisko, K. (2022). Public sector's role in public-private climate collaboration-Large Finnish companies' perception of the role of municipalities.
https://aaltodoc.aalto.fi/bitstreams/016274e9-a44f-43de-b852-f89bd2829b9a/download

Leander, K. M., Phillips, N. C., & Taylor, K. H. (2010). The changing social spaces of learning: Mapping new mobilities. *Review of research in education*, *34*(1), 329-394.
https://www.academia.edu/download/73309391/1edd806aa57d96fb0e4ed3cc810826f893c4.pdf

Li, Z. (2020). *Pipeline Spatial Data Modeling and Pipeline WebGIS*. Springer International Publishing.

lo Storto, C. (2020). Measuring the efficiency of the urban integrated water service by parallel network DEA: The case of Italy. *Journal of Cleaner Production*, *276*, 123170.
https://journals.sagepub.com/doi/pdf/10.1177/21582440211005752

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in planning*, *62*(1), 3-65.
https://www.academia.edu/download/32603528/Malczewski_2004.pdf

Mishra, S., & Tyagi, A. K. (2022). The role of machine learning techniques in internet of things-based cloud applications. *Artificial intelligence-based internet of things systems*, 105-135.

Mpuon, J. A., Etim, G. S., Offiong, A. I., & Enouh, R. O. (2021). The role of event marketing in entrepreneurship development of firms in hospitality industry. *International Journal of Hospitality and Tourism Systems*, *14*(2), 25.
https://link.springer.com/article/10.1007/s10100-019-00635-y

Nordström, P. (2018). Creative landscapes: Events at sites of encounter. *Doctoral diss., University of Turku*.

Okwori, E., Pericault, Y., Ugarelli, R., Viklander, M., & Hedström, A. (2021). Data-driven asset management in urban water pipe networks: A proposed conceptual framework. *Journal of Hydroinformatics*, *23*(5), 1014-1029. https://pdfs.semanticscholar.org/ee44/027043bf4990472d91009c7ea4edb8d23d6b.pdf

Osemwowa, E., Omoruyi, I. M., Kurittu, P., Heikinheimo, A., & Fredriksson-Ahomaa, M. (2021). Bacterial quality and safety of raw beef: A comparison between Finland and Nigeria. *Food Microbiology*, *100*, 103860. https://www.sciencedirect.com/science/article/pii/S0740002021001258

Österman, A. (2014). Map visualization in ArcGIS, QGIS and MapInfo. https://www.diva-portal.org/smash/get/diva2:729183/FULLTEXT01.pdf

Pepe, M., Costantino, D., Alfio, V. S., Vozza, G., & Cartellino, E. (2021). A novel method based on deep learning, GIS and geomatics software for building a 3D city model from VHR satellite stereo imagery. *ISPRS International Journal of Geo-Information*, *10*(10), 697. https://www.mdpi.com/2220-9964/10/10/697/pdf

Pohjolainen, M. (2020). Disappearing islands–Cognitive capital, urban renewal and public art in Kalasatama and beyond. https://aaltodoc.aalto.fi/server/api/core/bitstreams/e9c51d8a-695c-48f3-8599-4f8ccb8f4318/content

Schokker, J., Sandersen, P., De Beer, H., Eriksson, I., Kallio, H., Kearsey, T., ... & Seither, A. (2017). 3D urban subsurface modelling and visualisation: a review of good practices and techniques to ensure optimal use of geological information in urban planning. https://nora.nerc.ac.uk/id/eprint/517808/1/TU1206-WG2.3-004%2B3D%2Burban%2BSubsurface%2BModelling%2Band%2BVisualisation.pdf

Salmensuu, O. (2021). *Essays on potato prices in developing countries: exploring potato potential as a time-tested tool for poverty alleviation and affordable welfare* (Doctoral dissertation, Itä-Suomen yliopisto). https://erepo.uef.fi/bitstream/handle/123456789/25933/urn_isbn_978-952-61-3823-7.pdf

Shi, W., Zhang, M., Zhang, R., Chen, S., & Zhan, Z. (2020). Change detection based on artificial intelligence: State-of-the-art and challenges. *Remote Sensing*, *12*(10), 1688. https://www.mdpi.com/2072-4292/12/10/1688/pdf

Shojaei, D., Kalantari, M., Bishop, I. D., Rajabifard, A., & Aien, A. (2013). Visualization requirements for 3D cadastral systems. *Computers, Environment and Urban Systems*, *41*, 39-54. https://www.academia.edu/download/45507222/Visualization_requirements_for_3D_cadastral_systems-Davood_Shojaei.pdf

Somu, N., MR, G. R., & Ramamritham, K. (2021). A deep learning framework for building energy consumption forecast. *Renewable and Sustainable Energy Reviews*, *137*, 110591.

Srivastava, P. (2020). *Innovative Approaches to 3D GIS Modeling for Volumetric and Geoprocessing Applications in Subsurface Infrastructures in a Virtual Immersive Environment*. West Virginia University.
https://researchrepository.wvu.edu/cgi/viewcontent.cgi?article=8618&context=etd

Steiniger, S., & Weibel, R. (2007). Relations among map objects in cartographic generalization. *Cartography and Geographic Information Science*, *34*(3), 175-197.
https://www.academia.edu/download/43691311/

Sun, A. Y., & Scanlon, B. R. (2019). How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions. *Environmental Research Letters*, *14*(7), 073001.
https://iopscience.iop.org/article/10.1088/1748-9326/ab1b7d/pdf

Tansel, B., & Zhang, K. (2022). Effects of saltwater intrusion and sea level rise on aging and corrosion rates of iron pipes in water distribution and wastewater collection systems in coastal areas. *Journal of Environmental Management*, *315*, 115153.
https://www.annualreviews.org/content/journals/10.1146/annurev-marine-020923-120737

Therrien, J. D., Nicolaï, N., & Vanrolleghem, P. A. (2020). A critical review of the data pipeline: how wastewater system operation flows from data to intelligence. *Water Science and Technology*, *82*(12), 2613-2634.
https://iwaponline.com/wst/article-pdf/82/12/2613/1102557/wst082122613.pdf

Tuomisto, T. (2023). *The main competence needs of circular economy in small-and medium-sized enterprises: case regions Hyvinkää and Satakunta.*
https://lutpub.lut.fi/bitstream/handle/10024/165988/Master%27s_Thesis_Tuomisto_Tiia.pdf?sequence=1&is-Allowed=y

Wang, J., Liu, G. H., Wang, J., Xu, X., Shao, Y., Zhang, Q., ... & Wang, H. (2021). Current status, existent problems, and coping strategy of urban drainage pipeline network in China. *Environmental Science and Pollution Research*, *28*(32), 43035-43049.
https://repositorio-aberto.up.pt/bitstream/10216/131915/2/440759.p

Wilenius, A. (2022). Nomadic Science Fiction: Experiencing Diversity and Alterity Through Urbanising Mongolia.
https://aaltodoc.aalto.fi/bitstream/handle/123456789/112594/isbn9789526405278.pdf?sequence=1&isAllowed=y

Wise, S. (2018). *GIS basics*. CRC Press.
http://crop-pattern.agri-es.ir/Portals/36/GIS%20Basics.pdf

Woodward, D., & Harley, J. B. (1987). The History of Cartography, Volume 1: Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean.

Yang, C., Wong, D. W., Yang, R., Kafatos, M., & Li, Q. (2005). Performance-improving techniques in web-based GIS. *International Journal of Geographical Information Science*, *19*(3), 319-342.

Zhu, J., Wright, G., Wang, J., & Wang, X. (2018). A critical review of the integration of geographic information system and building information modelling at the data level. *ISPRS International Journal of Geo-Information*, *7*(2), 66.
https://www.mdpi.com/2220-9964/7/2/66/pdf