NOVA IMS Information Management School

MDSAA

Master Degree Program in

Data Science and Advanced Analytics

AI-Infused Smart Cities

Transforming Kosovo's Urban Landscape for Sustainable Growth

Engjulla Hasani

Master Thesis

presented as partial requirement for obtaining a Master's Degree in Data Science and Advanced Analytics

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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AI-Infused Smart Cities

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By

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Master Thesis presented as partial requirement for obtaining the Master's degree in Data Science and Advanced Analytics, with a specialization in business analytics.

Supervisor: Vitor Manuel Periera Duarte dos Santos, PhD, NOVA Information Management School

July, 2024

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

[Portugal, 2024]

Engjulla Hasani

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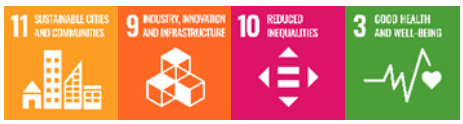
Abstract

The focus of this research is to apply artificial intelligence (AI) to design a new intelligent city in Kosovo. Specifically, it, in three areas sustainable urban development; traffic control efficiency; increased services for the public. This research follows the ideas of Design Science Research (DSR), using new solutions to comprehensively handle complicated city problems. After closely examining existing research, an analysis of the essential components of smart cities was made, including intelligent economics, mobility, environmental protection and improvement, population patterns and lifestyles as we know them now with the users themselves included in the design process. Drawing upon the work of both Hoxha and Pallaska, which is consistent with Sustainable Development Goals (SDGs), this thesis offers a tailored framework for Kosovo. Utilizing such a strategy, AI can improve automobile mobility accordingly through advanced decisions support systems. State-of-the- art fresh air filtering systems, one designed for urban and another for suburban conditions respectively, can quickly and thoroughly deal with pollutants in the atmosphere. A new model of waste management, in line with the sustainable development goals, must take advantage of AI to remain efficient. It must also put right overenthusiasm after too many mountains of salesman words to the on-site digestion; Until car media or owners are willing to accept low cost, bulky equipment that works mainly. The ethical use of AI, which this research also investigates, is particularly insistent on addressing itself to become more inclusive and open. It forces us to reduce bias in our data collection, protect privacy, establish accountability and build systems for transparent decision-making so that technology becomes responsible and fair. Also focusing on open data initiatives, the research emphasizes the significance of promoting transparency and citizens' participation in management of the intelligent city region. Its research approach involves comprehensive evaluation and validation techniques for investigating points put forth making sure that they can be applied in practice and expanded.

The study's goal is to give practical suggestions to policymakers, urban planners and all stakeholders in Kosovo so that they can use AI to transform the urban environment. This thesis also enriches an ongoing dialogue about future directions for urban innovation, intelligent urbanization in developing countries as well as other currently preferred nomenclature by recommending that smart city development be pursued in a manner that is sustainable resilient and intelligent at once.

Keywords: Smart Cities; AI; Sustainable Urban Development; Traffic Management; Enhanced Public Services

Sustainable Development Goals (SDG):



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LIST OF ABBREVIATIONS AND ACRONYMS

AI - Artificial Intelligence
AMI - Advanced Metering Infrastructure
ANN - Artificial Neural Networks
DER - Distributed Energy Resources
DL - Deep Learning
DR - Demand Response
DSR - Design Science Research
EU - European Union
EV - Electric Vehicle
GIS - Geographic Information Systems
ICT - Information and Communication Technology
IoT - Internet of Things
ITS - Intelligent Transportation Systems
LSTM - Long Short-Term Memory
MaaS - Mobility as a Service
ML - Machine Learning
MOOC - Massive Open Online Course
MSE - Mean Squared Error
ODK - Open Data Kosovo
PCA - Principal Component Analysis
PM2.5 - Particulate Matter 2.5 micrometers
PPP - Public-Private Partnership
RNN - Recurrent Neural Network
SDG - Sustainable Development Goals
SHAP - SHapley Additive exPlanations
SOMO35 - Sum of Ozone Means Over 35 ppb
SVM - Support Vector Machines
TL - Transfer Learning
UBO - University of Business and Technology
USAID - United States Agency for International Development
V2X - Vehicle-to-Everything

1. INTRODUCTION

1.1. Background and problem identification

The concept of smart cities stands as a beacon of innovation in the face of escalating urbanization and technological progress. These cities integrate advanced technologies and data-driven methods to boost efficiency, sustainability, and the overall quality of life. A central element in this transformation is the use of artificial intelligence (AI), which allows for the intelligent use of data in decision-making and generating predictive insights (Din et al., 2019). The development of smart cities illustrates a progressive approach to urban living, aiming to create environments that are not only efficient but also resilient and prepared for the future.

In Kosovo, particularly in its capital, Pristina, there is a vivid depiction of an urban renaissance, Pristina has experienced a dramatic increase in its population, growing from about 109,000 people in 1981 to approximately 220,000 in 2022, with actual figures possibly higher when accounting for daily and weekly commuters and temporary residents who work and study in Pristina. This burgeoning population has brought Pristina to the forefront of urban development challenges, making it a crucial arena for the deployment of smart city initiatives and AI-driven solutions. AI plays an indispensable role in refining urban living by enabling the analysis of extensive data sets, optimizing resource distribution, and forecasting future trends with remarkable accuracy. In Kosovo AI could provide customized solutions to problems like traffic congestion, inefficient public service, and air pollution. By leveraging data, AI algorithms could improve transportation systems, enhance energy management, and boost overall urban quality of life (UNDP,2022).

1.2. Objectives

The core objective of this research is to establish guidelines for the strategic use of Artificial Intelligence (AI) to enhance urban sustainability and bolster resilience in urban environments. The main goal of this research is to develop a tailored framework for Kosovo's urban environment, utilizing AI to improve traffic, air quality, and waste management

To achieve this, the study defines several intermediate key objectives:

Exploration of the Smart Cities Concept: Examine the Smart Cities concept, identifying opportunities and challenges in improving urban sustainability and resilience.

In-Depth Analysis of AI Implementation in Smart Cities: Thoroughly investigate the role of AI within Smart Cities, mapping current applications, trends, and areas for improvement.

Guidelines Development: Formulate practical guidelines for effective AI implementation in urban contexts

Development of a Smart Cities Framework for Kosovo: Develop a localized framework for Smart Cities in Kosovo to provide a contextual basis for AI integration

Guidelines Validation: Test and validate the developed guidelines.

1.3. Importance and Relevance

By integrating AI-driven solutions, the project aims to promote sustainable urban development in Kosovo. It can assist in improving transportation systems and enhancing environmental sustainability. This contributes to the long-term growth and well-being of urban areas, ensuring they evolve in harmony with the environment and the needs of their inhabitants. Addressing traffic mobbing is a central focus of the project. AI-powered traffic management can lead to more efficient transportation networks, reduced commute times, lower fuel consumption, and reduced greenhouse gas emissions. These improvements not only enhance the quality of life for residents but also support economic development by increasing productivity (Kourtit, Nijkamp, & Steenbruggen, 2017).

1.4. Empowering Kosovo's Government

The outcomes of this research project will empower the government of Kosovo in multiple ways. By providing data-driven insights and machine learning strategies, the government can make informed decisions related to urban planning, resource allocation, and policy development. This leads to more efficient governance and optimized resource utilization, resulting in cost savings. Additionally, the government's commitment to environmental goals, reflected in cleaner air and sustainable practices, demonstrates its dedication to improving living conditions for its citizens. (Zamponi & Barbierato, 2022). AI-enhanced traffic management can reduce commute times and ease congestion, making transportation more efficient. Enhanced public services, driven by AI, can provide quicker responses to citizen inquiries and improve the overall quality of urban living. This will also have a direct and positive impact on the daily lives of Kosovo's citizens. Furthermore, the potential for economic growth, driven by more efficient urban systems, can create job opportunities and boost the economic prospects of residents (Burd, 2016)

2. METHODOLOGY

2.1. Principles of Design Science Research

The paradigm of Design Science Research (DSR) is widely used in engineering, particularly in information systems (Peffers et al., 2007). This technique is crucial in domains that prioritize the development of efficient artifacts, especially in the sphere of data analysis. UDA refers to non-random subsets or derivative digital products that an intelligent agent, whether it be a human or software, creates from data sources after specific data manipulations. The inclusion of labeled datasets or training and testing datasets as well as information artifacts emphasizes the significance of data and information artifacts in data analysis. These artifacts encompass the intended results of a solution and the essential specifications for data visualizations or requirements. The idea to apply a DSR strategy becomes tempting due to the complex issues presented by fields such as smart city development, sustainability, traffic management, and public services (Albino, 2015). The iterative nature of data science research (DSR) is well-suited to the dynamic progression of urban development and smart city technologies, facilitating an ongoing improvement of solutions boosted by artificial intelligence (AI). This methodology fosters creativity and innovation while also being closely connected to the growing trend of integrating artificial intelligence (AI) into smart city solutions. It aims to tackle real-world challenges while simultaneously generating theoretical knowledge and practical solutions that can have a positive impact on the smart cities in Kosovo.

2.1.1. Core Features of DSR

DSR possesses distinct qualities that differentiate it from other research approaches, notably in the domain of information systems (IS). Contrary to conventional research methods that primarily concentrate on comprehending and elucidating phenomena, DSR is intrinsically geared towards problem-solving and finding solutions. The objective is to generate novel objects, such as processes, products, or systems, that effectively address particular and pragmatic issues (Hevner et al., 2004). The development of innovative artifacts is a fundamental attribute that distinguishes DSR from empirical research approaches, which primarily involve observation and action. Moreover, DSR places significant emphasis on the significance of utility, asserting that the objects created must offer tangible advantages in the actual world. One notable characteristic of this approach is its iterative nature, where the design process includes a series of cycles, including creation, testing, and refining, to achieve predetermined targets (Peffers et al., 2007). The origins and development of DSR in IS research may be attributed to the initial contributions of Simon (1996), who posited that the study of design represents a crucial domain of knowledge separate from the natural sciences. Simon's influential publication, "The Sciences of the Artificial," established the conceptual underpinnings for Design Science and Robotics (DSR), highlighting design as a scientific endeavor centered on the artificial fabrication of both physical and non-physical objects. The official acknowledgment of Design Science Requirements (DSR) within the Information Systems (IS) community had a surge in popularity during the early 1990s . The observation that the process of designing information systems frequently required the development of novel solutions to complex

problems—a task that fits well with the principles of design science—was the driving force behind this (March & Smith, 1995). Over time, the DSR approach underwent additional refinement and codification.

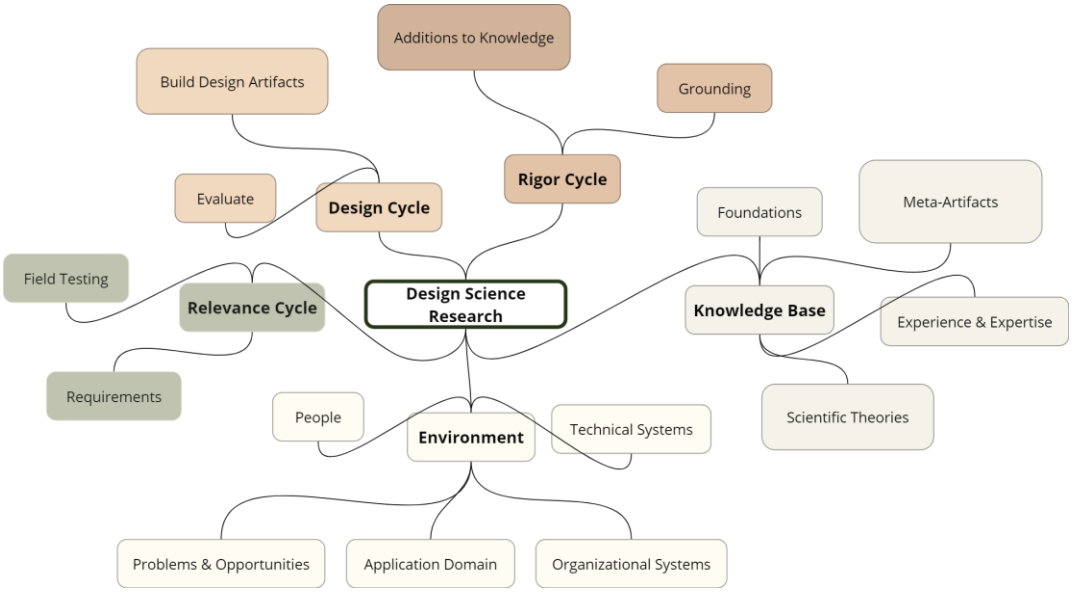

Figure 1 - Components of Design Science Research

The framework Hevner et al. (2004) proposed delineated the principles for conducting Design Science Research (DSR) in Information Systems (IS), emphasizing the significance of rigor, relevance, and design in research endeavors. This paradigm emphasizes the two main objectives of DSR: to enhance the existing knowledge base and to tackle real-world business challenges. In a further study, Peffers et al. (2007) proposed a DSR methodology that presented a more organized procedural framework for the implementation of design science projects as seen in Figure 1. This framework encompassed many stages, including issue identification, solution objectives, design and development, demonstration, assessment, and communication. This model has been extensive, highlighting the process-oriented aspect of DSR and offering academics a well-defined framework for doing research in design science. The development of Decision Support Systems (DSR) in the field of Information Systems (IS) has been marked by an increasing acknowledgment of its significance in tackling the ever-changing and intricate difficulties associated with the creation and execution of information systems. The focus placed by DSR on practical solutions, with its rigorous methodological techniques, has become an essential component of IS research. The advancement of technology has facilitated innovation, enabling researchers and practitioners to create and implement systems that are both technologically sophisticated and precisely tailored to user requirements and organizational objectives.

The implementation of AI-enhanced solutions in smart cities represents a convergence of DSR's strengths. AI technologies, such as machine learning algorithms and predictive analytics, are central to the development of smart city solutions, from optimizing energy usage in buildings to enhancing public safety through surveillance and anomaly detection. DSR facilitates the design of these AI-enhanced solutions by providing a structured methodology for their development, testing, and refinement. Moreover, DSR's

emphasis on evaluation ensures that these solutions are not only technologically advanced but also socially acceptable and environmentally sustainable (Von Alan, R. H., et al., 2004). One of the specific advantages of using DSR in this context is its ability to bridge the gap between theory and practice. By focusing on the creation of artifacts that address real-world problems, DSR ensures that research outcomes have practical relevance and immediate applicability. This is particularly important in the fast-paced environment of smart cities, where technological solutions must rapidly adapt to changing conditions and emerging challenges (Peffers, K., et al., 2007).

2.2. Research Execution and Methodology

Through data-driven insights and innovative strategies, the aim is to create smart cities that enhance quality of life while addressing environmental issues and strengthening urban resilience. This investigation comprises five key phases: (1) Establishing a Framework within the context of Smart Cities in Kosovo, (2) Exploring Smart City Concepts in-depth to assess their potential in enhancing urban sustainability and resilience, (3) Conducting a comprehensive study on the integration of AI in Smart Cities, which includes the development of personalized algorithms for specific framework components, (4) Formulating comprehensive guidelines, and (5) Validating the developed guidelines.

All aiming to conclude the same question: “How can AI-driven solutions empower Kosovo's smart cities in achieving sustainable urban development, optimizing traffic management, and enhancing public services?”

The research methodology, Design Science Research, will be implemented using the Hevner approach. Thus, the knowledge will be acquired in two distinct ways (cycles): The Rigor Cycle and the Relevance Cycle as it is shown in Figure 2.

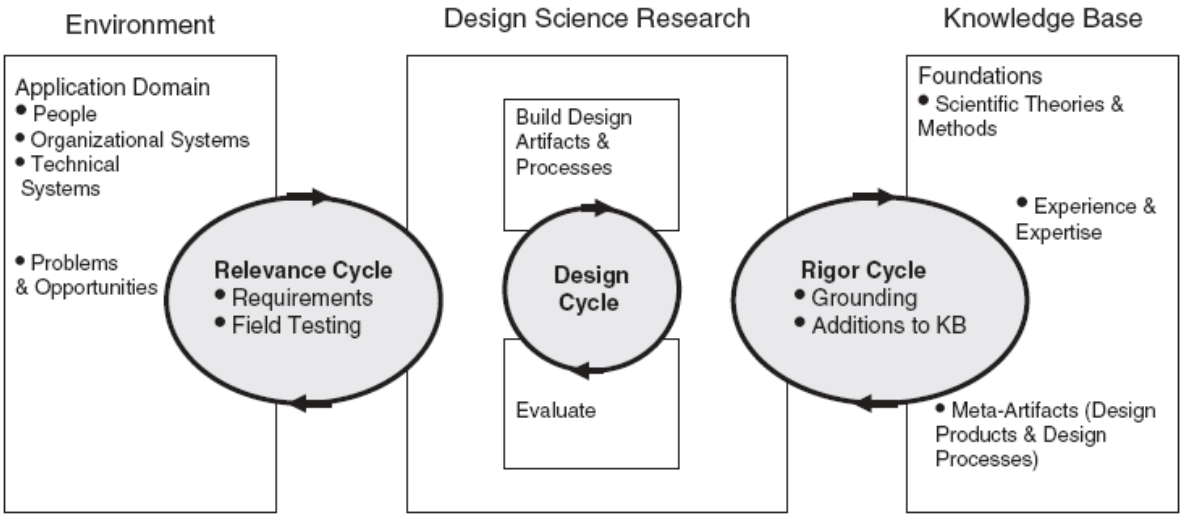

Figure 2 – Hevner Approach

2.2.1. Implementing DSR in Kosovo's Urban Context

The following table outlines the steps of the Design Science Research (DSR) process, specifically adapted to address the unique urban challenges in Kosovo. Our focus is on sustainable urban development, improving traffic management, and enhancing public services. Each step, from identifying the problems to reflecting on what we've learned, is aimed at developing AI-driven solutions that are not only cutting-edge but also highly practical for real-world application.

Table 1 – Implementing DSR in Kosovo's Urban Context

DSR Process Steps	Description	Developing the guidelines
1. Problem Identification and Definition	Identifying and defining a practical problem or opportunity involves an extensive review of the literature and empirical observations to understand the problem's context.	Identify challenges and opportunities in Kosovo's smart cities, with a focus on sustainable urban development, traffic management, and public service enhancement.
2. Objective and Requirements Specification	Formulating clear objectives and design requirements for the artifact to be created, serving as criteria for evaluating the solution.	Define research objectives and specify design requirements for AI-enhanced solutions targeting identified urban development challenges.
3. Design and Development	Involves the actual design and development of the artifact, which can be a prototype, system, model, or another innovative artifact designed to address the identified problem.	Develop a conceptual framework for integrating AI into Kosovo's smart city context, including personalized algorithms and systems.Define sucess metrics.
4. Demonstration	Showcasing the artifact to illustrate how it addresses the identified problem often involves a demonstration of the solution's practical functionality and utility.	Implement and test AI artifacts within Kosovo's urban environment through simulations and predefines success metrics, showcasing their real-world applicability.
5. Evaluation	Systematically assessing the effectiveness and efficiency of the artifact using methods like experiments, case studies, and usability testing.	Evaluate the impact of AI-enhanced solutions on sustainable urban development, traffic management, and public services in Kosovo.

6. Communication and Dissemination	Communicating the outcomes of the research through papers, reports, or other publications, sharing knowledge with the academic community and stakeholders.	Disseminate research findings and outcomes through scholarly publications and forums, ensuring knowledge transfer to relevant stakeholders in Kosovo.
7. Reflection and Learning	Reflecting on the DSR process and lessons learned allows for the refinement of design theories and contributions to the knowledge base.	Reflect on the insights gained during the research process, using this reflection to refine design theories and enhance AI applications in smart city development.

2.2.2 Foundation of Framework: Insights from Hoxha and Pallaska's Survey

This study builds upon a comprehensive questionnaire conducted by Hoxha and Pallaska (2023) where 1535 participants provided valuable information on administration and infrastructural developments in Prishtina. The survey results form the basis for the governance framework of smart cities since it provides first-hand contacts of the target population. The original survey data is then reprocessed to apply results of the modern statistical methods and advanced algorithms to find common patterns and correlations and to determine where more attention should be paid. The paper, with the name of "A study of components predicting smart governance in Prishtina, Kosovo", presents the principal component analysis and regression analysis both applied for the relevant sample of 1536 respondents with the help of the stratified probability sampling to determine which components are the most essential for the prediction of smart governance. The results show that the extent of smart city management and smart collaboration were the most important factors among all the indicators, where the aspect of smart management turned out to be slightly more influencing. More precisely, it revealed the significance of the coefficient R^2 that amounted to 0. 346, indicating that 34. These two components accounted for 6% of smart governance. Transportation granted, public services, technology application, openness, and data openness were identified to be significantly predicted and that smart city management stood out to be the best predictor. This component alone explained a rather large proportion of the variability in smart governance effectiveness regarding furthering smart city undertakings, positing the merit of proper management practices. Stakeholder management, the residents' engagement and proper coordination between various interest groups also revealed as critical success factors which supports the fact that collaboration is a key factor to undertake effective implementation of smart city projects. A more detailed analysis which can be found in section 4.2 was conducted to help develop the guidelines.

2.2.3 Incorporating Sustainable Development Goals into Framework Design

The framework is designed to align with specific Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). This alignment ensures that the framework not only addresses operational efficiencies but also contributes to environmental sustainability and resilience

2.2.4. Ethical AI Deployment in Smart Cities

In this paper careful considerations have been made to address the implications of AI systems as discussed in the study "IfQA; A Dataset, for Open domain Question Answering under Counterfactual Presuppositions" (2023). The focus on reasoning in AI emphasizes the importance of guidelines that reduce bias, safeguard privacy ensure accountability and promote transparency. By incorporating these principles the guidelines aim to prevent misuse and misinformation ensuring that AI applications have an impact on society in smart city scenarios. This approach demonstrates a commitment to deployment of AI following practices and building public confidence, in AI technologies.

Bias in AI can lead to unfair and discriminatory outcomes. To mitigate bias, it is essential to:

Data Diversity: It is advisable that training data sets should be conducted to perform various demographics of people.

Regular Audits: There are no accounts for one of the practices that have to be implemented and audited periodically, namely pre-specified decision-making logic AI systems must employ to detect biases.

Inclusive Design: Get more teams into the development process to exploit other potentials without any form of prejudice.

The final right is privacy right, and it relates to something that has to be guarded concerning the application of Artificial Intelligence. Key guidelines include:

Data Anonymization: Employ techniques in erasing such aspects not to recognize specific people.

Consent Mechanisms: Limitations on the collection and use of users' data by entities should be defined.

In line with the accountability of errors and misuse in AI systems there is Argyris' argument that these systems possess attributes that can get in the way of the abuse of power or make it possible to punish those who abuse power. This can be achieved by:The following can be done:

Traceability: So that AI system decisions and data flow traceability could be done and records should be maintained properly.

Responsibility Frameworks: Enforcement of regulation standards on the use, development, and regulation of AI solutions by various institutions.

Redress Mechanisms: Permit people to freely report their losses or any damage caused by AI systems and develop avenues by which any person can escalate the complaint against any wrong done by a particular system.

It is believed that accountability fosters trust on the artificial intelligence among the users and shareholders. Generally, activities aimed at raising the level of informer activities are as follows:

Explainability: Therefore, if these guidelines are observed, the future AI systems should be in a position to explain the reasons as to why they are doing a particular thing and this in the understanding of an average human being.

Through such guidelines, the use of AI in smart cities can be done appropriately, helping to improve the quality of the people's life in cities while maintaining ethical principles. Technique of bias, privacy, accountability and transparency should be applied to understand how AI should be used for societal benefits. Based on those guidelines, which harmonize with the best practices, it not only discourages the misuse and misrepresentation of AI but also paves the way to a future that fosters the beneficial role of AI in society.

2.2.5. Elaborating the Guidelines Development Process:

The development of practical guidelines for AI implementation in urban contexts involves a multi-step process to ensure they are both effective and applicable to Prishtina's unique urban environment.

1. Literature Review: An extensive review of existing literature and best practices in AI implementation for smart cities is conducted to gather insights and frameworks that can be adapted to Prishtina.
2. Expert Consultation: Insights from local and international experts in AI, urban planning, and governance are incorporated to ensure the guidelines are comprehensive and contextually relevant.
3. Drafting Guidelines: Based on the literature review and expert consultations, draft guidelines are formulated. These guidelines cover various aspects of AI implementation, including data privacy, bias mitigation, accountability, and transparency.
4. Evaluation: To evaluate the developed guidelines, establish standards focusing on relevance, clarity, practicality, stakeholder engagement, and innovation, and then assess these through qualitative measures such as stakeholder feedback and practical feasibility, alongside quantitative metrics like implementation rate, impact on urban issues, and compliance rate.
5. Finalization: Based on the evaluation results, the guidelines are finalized and documented. The final guidelines are designed to be scalable and adaptable to other urban areas in Kosovo.

3. LITERATURE REVIEW

3.1. The Smart City Paradigm: Understanding Its Core Concepts and Strategies

According to the British Standards Institute (2014), smart cities encompass the integration of human, digital, and physical systems within the built environment. These cities aim to foster a successful, inclusive, and sustainable future for their residents. Smart cities refer to metropolitan areas that integrate Internet of Things (IoT) technology to collect electronic data from sensors distributed across the city's infrastructure, buildings, and transportation systems. The real-time availability of this information facilitates the administration of essential municipal services, including water, energy, and transportation. Furthermore, Albino et al. (2015) emphasize the importance of information and communication technology (ICT) in promoting economic and sustainable urban development, enabling inclusive governance, and enhancing urban operations. Numerous authors have recently examined the idea of smart cities in-depth, highlighting various aspects and applications. Smart cities leverage IoT and ICT to create interconnected systems that enhance the efficiency, sustainability, and quality of urban life. By collecting and analyzing vast amounts of data in real-time, these cities can optimize resource use, improve service delivery, and reduce environmental impact. For instance, smart grids can balance energy supply and demand, smart water systems can detect and repair leaks, and smart transportation systems can reduce traffic congestion through dynamic route planning. Additionally, the integration of digital technologies fosters greater civic engagement and transparency. Residents can interact with city officials, access public services, and participate in decision-making processes through digital platforms. This inclusive approach not only improves governance but also empowers citizens and strengthens community bonds. The need to address the complex issues of urbanization, such as population growth, environmental sustainability, and economic resilience, is what has sparked the development of smart cities. By harnessing the power of technology, smart cities aim to create a more adaptive, responsive, and resilient urban environment that meets the diverse needs of its inhabitants (ITU, 2019).

3.1.2. Defining the Criteria for a "Smart" Urban Area

Several authors have attempted to delineate the concept of smart cities from others of a similar nature. Although a universally agreed-upon definition of a smart city is lacking, various characterizations share a common ground: the application of technologies to address challenges pertaining to the quality of life (Galati 2018). In certain instances, a smart city has been touted as a panacea for resolving urban issues since it encompasses every facet of urban existence (Dameri 2017). Urbanization, city expansion, and the associated challenges such as traffic congestion, pollution, and energy usage are commonly linked to the adoption of the smart city paradigm (Galati 2018). Social equity, or the application of technology to enhance the community, is one of the goals (Lehr 2018). Additional objectives include improved governance, services, economic and educational opportunities, and social equity. Although cities value the reputation of smart cities highly (Dameri 2017), there is an additional concern regarding the promotion of the city as an attractive destination (Galati 2018). According to Richard Florida's (2004) definition of the "creative class," a smart city has the potential to draw a more talented and creative population. Human capital and education are considered key drivers of urban expansion (Lee et al. 2013).

Smart economy, smart mobility, smart environment, smart people, smart life, smart living, and smart governance are the six primary components that comprise the concept of a smart city (Lee et al. 2013). To achieve smart city status, the following dimensions are targeted. As of now, the compilation of all these facets of smartness in a singular location remains an aspiration, as there is no case study that embodies this vision. Galati (2018) outlined a number of factors that each of these dimensions encompasses:

- Smart economy: efficiency in energy use; innovation, economic impacts, and return on investment; circular economy
- Smart mobility: intelligent transportation and transport systems, intelligent parking solutions, traffic management, mobility-as-a-service
- Smart environment: water and waste management, monitoring of environmental indicators, sustainable processes and urbanization, hybrid approaches to manufacturing
- Smart people: connected citizens, workers, and visitors; e-health; e-learning
- Smart living: smart spaces, advanced materials, public security and urban resilience
- Smart governance: digital automation of processes, open data, citizen participation

According to Dameri (2017), there should be three complementary qualities that determine the level of intelligence present in each of these components:

Effectiveness, since a smart city must create value for its citizens

Environmental considerations, preventing at least further environmental degradation

Innovation: using technology to reduce environmental impacts and deliver better services

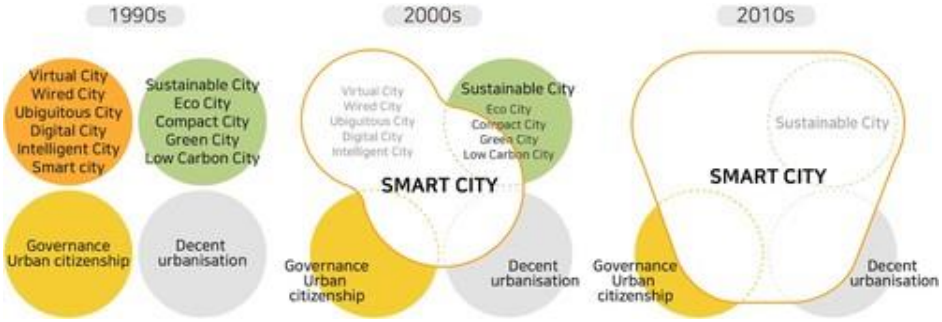

Figure 3 – Smart City Evolution

The diagram in Figure 3 illustrates the evolution and convergence of various urban concepts into the broader notion of the smart city over three decades. In the 1990s, the focus was on virtual, wired, ubiquitous, digital, and intelligent cities, with emerging concepts like smart cities. By the 2000s, these ideas expanded to include sustainable, eco, compact, green, and low-carbon cities, all increasingly interconnected under the smart city umbrella. Governance, urban citizenship, and decent urbanization were also key themes during this period. In the 2010s, the smart city concept further absorbed these diverse urban models, predominantly focusing on sustainability and smart urban development, signifying a comprehensive integration of earlier urban theories into a unified smart city framework.

3.2. Key Components of the Smart Economy

In smart cities the idea of smart economy is considered to be one of the most important ones. It refers to the fusion of digital technology and advanced methodology into the economic systems and business models with the goal of boosting productivity and endurance. With cities all over the world seeking to become smarter the concept of smart economy has emerged as an essential area of study to facilitate sustainable and efficient growth of the economy through the use of technology. A solid foundation of physical networks is the vital element of smart economy as it enables the connection of various sectors and smooth operation of many services. Internet, particularly fast broadband connections, IoT systems and superior data centers are some of the notable parts (Batty et al. , 2012). For instance, fiber-optic connections offer the capacity required in the advanced web association that allows quick exchange of data in real time which embrace wise applications like telemedicine and wise education, smart utilities among others. The smart economy leads to the unbounding of the existing 'blueprints' of doing business and identifies new opportunities to grow by building new business models as discussed further under Table 2 The concept of sharing economy as depicted by Airbnb and Uber shows how technology-enabled platforms can foster marketing new opportunities for value creation (Sundararajan, 2016). Fintech innovations are better financial services by using mobile, peer-to-peer and even Blockchain as a way of facilitating the services (Gomber et al. , 2017). E-commerce platforms offer value addition services which enrich the consumer satisfaction and optimise the functioning process (Kotha, 2019).

3.2.1. Talent and Education: Building a Digitally Skilled Workforce

The creation of a smart economy necessitates having a talented workforce which will be conversant with the digital tools. Employment of educations and training that can enhance the skills on issues to do with digital are very essential (Carretero et al., 2017). Such interventions like coding bootcamps, online courses, or stem education are useful in readiness of the upcoming generation for the job markets in the digital economy (McKinsey Global Institute, 2018). For instance, technology organizations and schools' collaboration can help students to gain practical experience in modern technologies.

3.2.2 Smart Grids: Enhancing Energy Efficiency and Reliability

Smart system of grids is one of the basic elements of the Smart Economy as due to it, we can have a considerable improvement in the trusted delivery of electricity. These grids use the ICT options within the power grid to provide control of the electric power stream, enhance its efficacy, and reduce the expenses (Fang et al . , 2012 the essential features are as follows:

Advanced Metering Infrastructure (AMI): AMI systems provide accurate information in as much as electrical power usage is concerned thus assisting the consumer in monitoring usage in a better way (Gungor et al. , 2011).
Distributed Energy Resources (DERs): Renewable energy sources such as surface of the sun and wind power have the positive attribute of enhancing the main grid integration of power reliability and energy sustainability (Lund et al. , 2015).
Demand Response (DR): DR programs only shift the demand as opposed to the supply and thereby help in balancing the supply-demand process and hence can help in preventing blackouts occurring at some

times of the year when demand is particularly high (Albadi & El-Saadany, 2008).
Grid Automation: Automation technologies enhance the ability of the system in detection and handling of the outages and other issues that may be facing the system hence at the same time cutting on the time of system inactivity as well as on maintenance costs (Bakken & Blumsack, 2010).

3.3. Recent Technological Developments in the Smart Economy

3.3.1. 5G Technology: Revolutionizing Connectivity

The smart economy needed networks of advanced speed and reliability which are offered by 5G. This technology is useful for developing sophisticated IoT applications like intelligent power distribution networks and self-driving cars because it enhances the rate of information exchange and decreases the response time (Gohil et al. , 2013). For example, the 5G networks in connected devices to allow swift and real-time exchange of data between the smart cities systems and alleviate the hassles of bulky infrastructures (Andrews et al. , 2014).

3.3.2. Blockchain Technology: Ensuring Security and Transparency

By utilizing blockchain technology, data can be secured and shared effectively for transactions and usage of smart contracts for rendering the effectiveness of economic processes and minimizing the occurrences of fraud (Nakamoto, 2008). This characteristic is one of the best in ensuring the data is safe and secure, and thus the best model for the use in the financial services, government and service industries, and supply logistics (Swan, 2015). For example, basic contracts minimize dependency on the middlemen and fasten processes since they are self-executing (Christidis & Devetsikiotis, 2016). Digital twins are virtual digital mirrors of physical assets where city economies can realistically experience, model, and enhance economic behaviors and spatial layouts in the actual environment in actual-time(Tao et al. , 2018). Digital siblings facilitate better decision making since they provide deeper information about the functionality of the urban systems including the infrastructure and transport networks (Negri et al. , 2017). For instance, digital twins can be used where and when it is necessary, for instance in improving the routes for public transport, development of the infrastructure, and traffic simulations (Grieves 2014).

3.4. Case Studies in Smart Economy Implementation: A Comparative Analysis

In today's fast-paced world, cities across the globe are embracing smart economy initiatives to boost their economic growth, enhance public services, and manage urban environments more effectively. This table provides a detailed comparative analysis of these initiatives in several leading global cities, each showcasing unique approaches and tangible benefits. Below are the most recent smart economic initatives taken by different cities and their benefits in the economy.

Table 2 – Comparative Analysis of Smart Economy Initiatives in Global Cities

City	Initiatives	Benefits	References
Barcelona	22@Barcelona project, comprehensive digital infrastructure, innovative business model promotion	Increased economic activity, improved urban management, higher citizen engagement, and innovation hubs	(22@Barcelona , 2024)
Singapore	Smart Nation initiative, heavy investment in digital infrastructure, AI, and blockchain	Enhanced public services, improved data security, greater efficiency in urban management, and a robust digital economy	(Smart Nation Singapore, 2024)
Amsterdam	Smart grids, digital citizen engagement platforms, support for smart startups	Improved energy efficiency, higher levels of public participation, and a thriving ecosystem for innovation	(Amsterdam Smart City, 2024)
London	Smart London Plan, connected transport, digital inclusion initiatives	Better transportation systems, increased digital inclusion, enhanced urban sustainability, and smart urban planning	(Smart London, 2024)
Helsinki	Helsinki Smart Region, MyData initiatives, urban labs for smart solutions	Enhanced data privacy and control, innovative urban solutions, and stronger community engagement	(Helsinki Smart Region, 2022)
Seoul	IoT-based smart city solutions, smart traffic management, public Wi-Fi expansion	Improved traffic management, enhanced connectivity, and increased access to public services	(Smart Seoul,2022)

3.5 The Concept of Smart Mobility in Smart Cities: Recent Developments

Smart transportation plays a role, in the development of smart cities by leveraging digital advancements and creative methods to enhance the efficiency, eco friendliness and user experience of transportation systems. With the expansion of areas and the emergence of environmental issues the significance of smart mobility solutions has grown substantially in establishing sustainable and effective transportation networks (Papa & Lauwers, 2015; Vliet et al., 2017).

3.5.1 Intelligent Transportation Systems (ITS)

Technologies which have however been integrated in ITS include the following with aim of increasing the likelihood and quality of traffic systems. This can be traffic control, real time traffic information, automatic collection of tolls among others Competitions in the system pushing public protection Transportation Systems The assistance offered through ITS for example incorporation of sensors, cameras and data analysis implies that traffic can be directed in an orderly manner with a view of emptying the roads while at the same time preventing incidences of loss of lives especially in cases whereby there are accidents ((ITS Department, 2007).

3.5.2. Autonomous Vehicles: Revolutionizing Urban Mobility

Autonomous Vehicles (AVs) are the driving force of urban transportation's transformation. Thanks to artificial intelligence, sensors and advanced algorithms, these vehicles operate on their own without human intervention, thereby helping to improve traffic efficiency as well as reducing accidents. They also offer mobility solutions for people with disabilities. They are a promising development in urban transportation, since they might well change urban geography and make towns strollable (Litman, 2018). The reduction in pollution and noise within the city cannot be realised without electric vehicles (EVs). A wide range of charging infrastructure that includes fast charge and wireless charging stations is the foundation for widespread use of EVs. Smart grid integration makes it possible to arrange power more efficiently and promotes the use of clean renewable energy sources (Mathematics, 2018).

3.6. Technological Evolution of Smart Mobility

3.6.1. Connected Vehicle Technology

V2X communication technology is one of the rapidly progressing digital technologies of vehicles. V2X is explained to be the ability for vehicles to exchange information with other auto-mobiles and with existing structures with regard to safety as well as smooth traffic flow. Other findings show that the V2X has evolved to become more feasible where latency and reliability were amongst the areas of enhancements (Chen et al. , 2023).

3.6.2. Geographic Information Systems (GIS): Assisting Urban Mobility Planning

GIS is applied when dealing with spatial data and is useful in decisions concerning mobility in urban areas. The GIS applications help in development of an efficient transport system, and; planning of the efficient routes, and; planning new linkages for transportation network system. Decision-making and planning of. Smart mobility projects are initiated by GIS according to Thill (2000).

3.7. Case Studies in Smart Mobility Implementation: A Comparative Analysis

As part of the smart cities' development across the globe, more metropolitan areas are implementing smart mobility approaches that increase the quality of transport, decrease traffic jams, and generally make urban life better. From the comparison of these initiatives in table 3, one can see that there are a variety of strategies and positive outcomes in the global cities.

Table 3 – Comparative Analysis of Smart Mobility Initiatives in Global Cities

City	Initiatives	Benefits	References
Barcelona	Development of bike-sharing systems, smart traffic management, and electric bus fleets	Reduced traffic congestion, lower emissions, increased use of sustainable transport modes	(Barcelona City Council, 2024)
Singapore	Autonomous vehicle trials, integrated public transport system, and nationwide EV charging network.	Enhanced public transport efficiency, reduced road accidents, and widespread adoption of EVs	(Smart Nation Singapore, 2024)
Amsterdam	Smart bike lanes, dynamic traffic light systems, and electric car-sharing services	Improved cycling infrastructure, optimized traffic flow, and increased electric vehicle usage	(Amsterdam Smart City, 2024)
London	Connected public transport system, congestion charging, and smart parking.	Better public transport connectivity, reduced traffic congestion, and efficient use of parking spaces	(Smart London, 2024)

3.8. The Concept of Smart Environment in Smart Cities: Recent Developments

Smart environment is one of the subdivisions of a smart city that aims at regulating and improving urban systems through technology integration. This extend to programs such as; Air quality control, Our wastes, Power conservation, and Natural resources among others. Due to the increasing effects of urbanization and global warming, intelligent environmental solutions have become crucial for the enhancement of the large cities' development.

For instance, the environmental monitoring applications which include sensing technologies for getting information through, IoT devices to monitor physical surroundings such as air quality, water quality, noise levels, and weather remain important in assisting in the management of urban environments and reducing impacts on the environment (Gershenfeld et al. , 2004). Smart waste management often integrates IoT sensors, data analysis or automated systems to enhance waste collection, recycling, and disposal by enhancing efficiency, increasing the recycling efficiency and decreasing operating cost (Zaman, 2014). A smart energy management system combines smart grid, renewable systems, and energy storage systems to efficient and effective utilization of energy and efficient distribution of energy and reduction in carbon energies while improving the use of renewable energy sources (Parida et al. , 2015).

Moreover, green infrastructure including green roofs, urban forests and permeable pavements, supports the inhabitation of many species, reduces the UCIs and manage storm waters better especially in ageing systems like that of Philidelphia (Benedict and McMahon, 2006). Advanced IT applications of water meters that incorporate sensors and sophisticated data processing enable the determination of water quality and areas of weakness as well as efficient watering control to enhance the efficient use of water in urban communities and enhance water systems (Savic and Walters, 1999). It is pertinent to realize that all these efforts promote a better health of cities but also help in emerging more sustainable urban systems.

3.9. Recent Technological Developments in Smart Environment

Due to recent advances in science and technology, environmental sensors based on the IoT are now more accurate and inexpensive than ever. Today's environmental sensors can provide such things as real-time air or water quality data as well as measurements for how loud the background noise gets when summertime hits Central Park. This is only one aspect of it though; there are now many useful kinds.

Low-Cost High-Precision Sensors: Known sensors such as these built by Libelium (B Biest-Sensor and Internet of Things Center) and Bosch(Efficient Smart Agriculture) marry high precision with low cost. A further economic credit for their development is to reduce capital investment in labour-intensive installation projects (Biem-Sensor Control, et al. 2012). Because they can measure high levels of accuracy particles in the air, concentrations gases, water quality and other things more than 10 times better than previous systems have been able to. Integration with cloud platforms: modern sensor data are stored and analyzed on cloud computing platforms, thus making it easy for people all over the world

to participate in real-time supervision. Data can also be archived and analyzed over long periods of time. In one instance, a move by IBM to join forces with pair sensor manufacturers has produced detailed environmental data which is changing the face of smart cities (IBM, 2024). Advanced Remote Sensing: new satellite environmental monitoring systems like those in the European Space Agency 's Sentinel series offer high definition images for urban and environmental studies (ESA, 2024). These satellites can follow up how air quality changes, urban heat islands develop and expand and where the green space lies in large cities.

3.9.1. AI-Enhanced Environmental Data Analysis

Total investment in environment-related AI companies has doubled in the past 10 years. To name just one example: As of 2024, from a global industry perspective, venture capital investment in the environment area has seen overall year-on-year growth. Recent re-searchers utilize advanced machine learning models to predict air quality and identify pollution sources. For example, Zhang et al.'s 2023 work applies deep learning models to forecast air quality in cities with high accuracy. AI for UHI Mitigation: Recent applications of AI algorithms focus on reducing urban heat islands in cities through analysis of satellite data and urban land use patterns. Dystopian scenarios and bad experiences with the current waste management systems and transportation networks can all be totally rewritten using new AI technology. Authorities including Waste Management Inc. have been doing things like this since 2024 with their waste management solution that adopts available resources and applies AI in optimization methods for route scheduling as well as for waste sorting at disposal sites (Waste Management Inc., 2024).

Waste Management Tracking: In waste management, blockchain technology offers a new approach for tracking and verifying waste management and recycling process. The Waste Ledger system is a typical example, which uses blockchain to record every stage of the waste management process. Waste Ledger ensures that every transaction is recorded on an unchangeable ledger and provides a clear and openly visible stream of waste. Not only does this system help to prove compliance with environmental regulations, but following its logic management practices are correspondingly improved through increased accountability. Such process efficiencies can lead to more efficient recycling operations and lessen the environmental impact of waste (Waste Management Inc., 2024).

3.10. Case Studies in Smart Environment Implementation: A Comparative Analysis

While there are different approaches as mentioned in Section 3.9 that different cities could undertake to have a environmental approach to urbanism, below in Table 4 are the most prominent real life cases, with most of them employing the waste management tracking approach.

Table 4 – Comparative Analysis of Smart Environment Initiatives in Global Cities

City	Initiatives	Benefits	References
Barcelona	Real-time air quality monitoring, smart waste collection systems, and green roofs	Improved air quality, efficient waste management, and enhanced urban green spaces	(Barcelona City Council, 2024)
Singapore	Nationwide water management system, smart grids for energy, and urban afforestation projects	Efficient water use, reduced energy consumption, and increased urban green areas	(Smart Nation Singapore, 2024)
Amsterdam	Smart water management, IoT-based air quality sensors, and extensive bike lanes	Enhanced water management, better air quality, and sustainable transportation options	(Amsterdam Smart City, 2024)
London	Smart energy management systems, urban greening initiatives, and real-time environmental monitoring	Reduced energy usage, improved urban biodiversity, and enhanced environmental data transparency	(Smart London, 2024)
Helsinki	AI-driven waste management, smart water meters, and renewable energy integration	Higher recycling rates, efficient water use, and increased use of renewable energy	(Helsinki Smart Region, 2022)

3.11 The Concept of Smart People in Smart Cities: Recent Developments

The "Smart People" component is essential to the development of smart cities. It highlights the roles that educated, skilled and involved citizens play in increasing innovation, social group descisions and sustainable urban development. Smart people deploy digital technology and build knowledge economy, participatory governance (Johnson et al., 2023). This section introduces the main parts of smart people as well as its recent technological developments.

3.11.1. Education and Lifelong Learning

Education and lifelong learning for citizens are essential for nurturing skillful, flexible workers. Smart cities work to develop the infrastructure of classes, digital literacy projects, and lifelong learning for people's skill set to meet present needs.

- Digital Classrooms: Fusion of technology in classrooms through digital whiteboards, online resources and the ability to learn interactively on social media platforms. (Johnson et al., 2023)
- E-learning Platforms: Expansion of online courses and MOOCs (Massive Open Online Courses) that give flexible learning opportunities to all age groups (Pappano, 2023).

3.11.2. Digital Literacy

Digital literacy is important so citizens effectively use digital technologies in their personal and professional lives. It includes the ability to access, analyze, and use information from digital sources responsibly. At USP (University of the South Pacific), large e-reading rooms are being set up. Mixed with the addition of properly resourced machines, they allow students to read their course materials and other related articles at any time, at any place. Community tech hubs are known as establishment of technology hubs in communities where citizens can access digital tools and receive training (West & Lansang, 2023). Digital inclusion programs are initiatives aimed at helping to bridging the digital divide by providing internet access and digital skills training to underserved populations (Van Dijk, 2023).

3.11.3. Citizen Engagement and Participation

Active citizen engagement and participation in governance processes promote positively transparency, accountability, and development of the community. Robust digital platforms in smart cities facilitate public participation in decision making. E-Government Services are online platforms This interactive systems allow citizens to access government services; submit complaints, requests for information, or appreciation at least； and participate in policymaking. (Scholl, 2023). Gifts of Participatory Budgeting: Digital tools now enable residents to vote on the budget allocations for local projects that 122 may represent hundreds of votes; translating civic participation from activist demonstration action (Sintomer et al., 2023)

3.11.4. Innovation and Creativity

Fostering a culture of innovation and creativity is essential for economic growth and social development in smart cities. This means nurturing start-ups, encouraging research and development (R & D), promoting creative industries. Innovation Districts: Formation of urban zones as innovation districts, with startups, research organizations, and innovative industries each clinging to their own niche (Katz & Wagner, 2023). Hackathons and Competitions: Meetings where people from different fields such as technology and finance come together to propose innovative solutions for urban problems, often drawing on their own experiences or those of others (Briscoe et al., 2023).

3.12 Case Studies in Smart People Implementation: A Comparative Analysis

Initiatives to increase digital literacy have made significant changes in initiators future workforce, below in Table 5 is a comparative analysis of different projects around the world.

Table 5 – Comparative Analysis of Smart People Initiatives in Global Cities

City	Initiatives	Benefits	References
Barcelona	Digital literacy programs, e-government services, and innovation hubs	Improved digital skills, increased citizen participation, and thriving startup ecosystem.	(Barcelona Digital City, 2024)
Singapore	Nation-wide digital inclusion initiatives, smart classrooms, and collaborative platforms	Enhanced educational outcomes, reduced digital divide, and robust collaborative networks.	(Smart Nation Singapore, 2024)
Amsterdam	Community tech hubs, participatory budgeting, and smart social programs	Greater community engagement, equitable resource allocation, and effective social interventions.	(Amsterdam Smart City, 2024)
London	Innovation districts, online learning platforms, and smart citizen engagement tools	Boosted innovation, improved lifelong learning opportunities, and enhanced civic participation.	(Smart London, 2024)
Helsinki	AI-powered education tools, digital diplomas, and co-working spaces	Personalized learning, secure credentialing, and dynamic work environments.	(Helsinki Smart Region, 2022)

3.13 Key Components of Smart Living

3.13.1. Healthcare and Well-being

Smart Living uses advanced healthcare solutions to build public health, leveraging modern technology (like telemedicine), wearable health devices and health information systems at every turn. Telemedicine provides remote medical consultation and other health services, which greatly improves accessibility to healthcare, particularly in remote or underserved areas; During telemedicine platform, for example, only professionals equipped with proper training can remotely diagnose diseases. Therefore it smoothly filled in some gaps that could previously not be known at all. Take OnAppNet in Wuhan for an illustration: The public provide simulated case files on various diseases as hard drives (one option each for Simulated Case Browsers and Simulated Treatment

Wearable health electronic devices such as smartwatches, health bracelets can quickly transfer vital signs and detailed health data in real time to the network. Encouraged by these gadgets, people are no

longer just passive patients. While daily activity, heart rate, sleep patterns are just some of the things woreables can monitor for us (Patel et al., 2015).Health care information systems provide an integrated platform for managing both individual medical records and global health data. They are thus one of the most efficient ways to distribute this type of information amongst its practitioners (Tanenbaum-Ross 2016).These systems allow those people engaged in the provision of health services to exchange patient data easily with others who are also partaking in similar activities, which better coordinates patient care and outcomes (Wager et al., 2017).Apart from health, smart technologies have a significant effect for public security. Emergency response times can be shortened and disaster management may be made more effective if the right technique is included (Fung, 2010). Equipped with AI-powered cameras and sensors, intelligent surveillance keeps an eye on public space, triggers an alert in case of suspicious activities and assists in real-time detection of crime prevention; therefore causing safer communities to emerge (Kumar et al., 2019).Data from various sources is now integrated in emergency response systems Extremely rapid response with up-to-the-minute information given to first responders is made possible by this modality, which makes a big difference for the efficiency and effectiveness of response operations (Veil et al., 2011). Disaster management tools are designed to anticipate and react to natural disasters, thereby lessening the harm that such events inflict on communities. By using data analytics and predictive modeling to foresee future disasters and lay out next steps for handling them as elegantly as possible. (Noji, 2005)

3.14 Case Studies in Smart Living Implementation: A Comparative Analysis

As the world seeks to make living in urban centers more fulfilling, becoming smart living cities that use technology to improve the livability of urban centers is fast becoming the order of the day. These initiatives include pillaring a variety of measures, covering from transportation and effective traffic and road disasters combating to electrical car utilization boost (Smart Nation Signapore, 2024) . Table 6 below contains the comparison of the above stated smart living initiatives, outlining the major differences in the approaches besides demonstrating that the implementation of such initiatives has produced considerable impact in a number of cities of the world.

Table 6 – Comparative Analysis of Smart Living Initiatives in Global Cities

City	Initiatives	Benefits	References
Dubai	Autonomous vehicle trials, integrated public transport system, and nationwide EV charging network.	Enhanced public transport efficiency, reduced road accidents, and widespread adoption of EVs	(Smart Nation Singapore, 2024)
Copenhagen	Community health monitoring, energy-efficient smart homes, and intelligent traffic systems	Better health outcomes, lower energy consumption, and optimized traffic flow.	(City of Copenhagen, 2024)

Tokyo	Smart public health programs, advanced home automation, and AI-driven emergency services	Enhanced public health, increased home efficiency, and improved emergency response capabilities.	(Tokyo Metropolitan Government, 2024)
Toronto	Wearable health tech, sustainable smart homes, and integrated disaster management systems	Improved personal health monitoring, sustainable living, and effective disaster response.	(City of Toronto, 2024)

3.15 The Concept of Smart Governance in Smart Cities: Recent Developments

Including digital technology to enhance the efficiency, transparency and inclusiveness of government functions is what is known as smart governance. At the same time, it involves e-government services, participatory governance, data-based decision making and measures to promote transparency and accountability. This section explores the key components of smart governance, and recent technological advancements that help support this part of smart cities. E-Government services employ computer platforms to more efficiently deliver public services. These platforms enable such things as online transactions, request for services and access to government information. By website or app online service access opening times and access points for public services more flexible, straightforward, more user-friendly to use. (Janssen & Estevez, 2013). The open government data movement is meant to provide the public with government information (Zuiderwijk &Janssen, 2014). Digital identity systems provide secure and convenient means of identity verification for online services, hence making e-government services more secure and more processive. (Bertot, Jaeger, & Grimes, 2010)

In participatory governance, citizens become involved in decision-making; digital tools help to support public consultation, the collection of feedback and collaborative policy-making. Digital learning is the practice of enabling people to study online and then learn in person. Massive Open Online Courses (MOOcs), for instance, use the Internet to offer cheap or free courses that people take when convenient on their computers or mobile devices anywhere with an Internet connection. The idea of OER has been taking root for a number of years. In 1998 the Commonwealth of Learning (CoL) and UNESCO were among pioneers publishing guidelines about how authors can free their material - such as books, videos, interactive exercises and games-in the public domain anywhere in the world (Smith, 2000). Citizen engagement platforms involve residents in surveys, forums, and consultations-as well as fostering a more inclusive decision-making process (Bonsón et al., 2012). Participatory budgeting platforms allow citizens to vote on budget allocations for local projects, ensuring that community needs and preferences are considered (Sintomer, Herzberg, & Röcke, 2008). E-petitions are digital systems that enable citizens to submit and support petitions on various issues, amplifying public voices in governance (Smith, 2009).Data-driven decision-making is a more recent phrase from the technology world, and it involves using data analytics to inform and improve governance processes. This includes analyzing trends, predicting outcomes, and optimizing resource allocation. The technology behind cryptocurrencies - blockchain technology - can be applied easily to keep immutable records of government transactions

and decisions in order that these things are transparent. It is hardly surprising, then, as Ølnes, Ubacht & Janssen (2017) say " this will help those who need information about public policy gain more trust in government '. The opening of government data for public access and checking by any interested person brings greater transparency and trust (Janssen, Charalabidis & Zuiderwijk, 2012). Government activities leave a digital audit trail. They bring transparency to financial management and make it easy for anyone with a computer. Recent developments have seen advanced survey platforms and interactive forums for policy-making discussions. CitizenLab is an engagement platform that lets governments open themselves to crowdsourced ideas and feedback from its citizens, making the decision-making process as transparent as possible. Above all, public 's will and input for" governance is also considered by CitizenLab (Susha,Gerlind Janssen, & Grönlund 2015).

3.16. Case Studies in Smart Governance Implementation: A Comparative Analysis

Cities globally are implementing smart governance initiatives to improve efficiency and transparency in urban administration. These efforts utilize digital technologies to engage citizens, streamline processes, and ensure secure online services. The following table provides a comparative analysis of these initiatives, highlighting different approaches and the significant benefits achieved in various cities.

Table 7– Comparative Analysis of Smart Governance Initiatives in Global Cities

City	Initiatives	Benefits	References
Tallin	E-government services, digital identity system, and open data initiatives.	Increased efficiency, enhanced transparency, and secure online services.	(e-Estonia, 2024)
Vienna	Participatory budgeting, citizen engagement platforms, and performance dashboards.	Greater citizen involvement, improved resource allocation, and better monitoring of public services.	(Vienna Digital City, 2024)
Seoul	Smart city dashboards, predictive analytics for urban planning, and digital audit trails.	Enhanced urban planning, proactive policy-making, and improved accountability.	(Smart Seoul, 2022)
New York	Mobile voting systems, online service portals, and transparency initiatives.	Secure and accessible voting, streamlined service delivery, and increased government transparency.	(NYC Digital, 2022)

3.17. The Imperative for Smart Cities?

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Interestingly for Prishtina, Kosovo, as displayed in the Figure 4 below, reveal an important environmental problem for Kosovo as it has a higher level of PM2. 5 and SOMO35 which are the key measures of air pollution compared to the average level of EU27. PM2. 5 particles are dangerous to human health because of their small size; the pass deep into the lungs and may even enter capillaries contributing to cardiovascular, cerebrovascular, and respiratory diseases. Likewise, higher SOMO35 suggests that people suffer from more adverse levels of ozone and chronic respiratory diseases; thus it impacts the citizens particularly children and the elderly (World Health Organization, 2018; European Environment Agency,2020).

Because of these environmental conditions, the establishment and deployment of smart city measures are not only pragmatic but necessary. With the help of Artificial Intelligence, IoT and big data analytics concepts, smart cities in the future will be able to revolutionize the existing methods of managing the environment through monitoring and predicting the changes in real time. This shows that such technological measures can go a long way in enhancing traffic circulation to minimize car pollution, generating methods of dispersing energy products effectively, and managing waste, hence efforts aimed at combating air pollution. In addition, using such systems, recommendations on the environmental standards and deployment of public health alerts can be forwarded to the policy makers for the promotion of the welfare of citizens. Therefore, the concept of smart city frameworks in the context of Kosovo is not just an evolutionary shift, but a progressive move that would contribute to a healthy and long future of Kosovo's cities (Batty et al. , 2012; Caragliu, Del Bo, & Nijkamp, 2011).

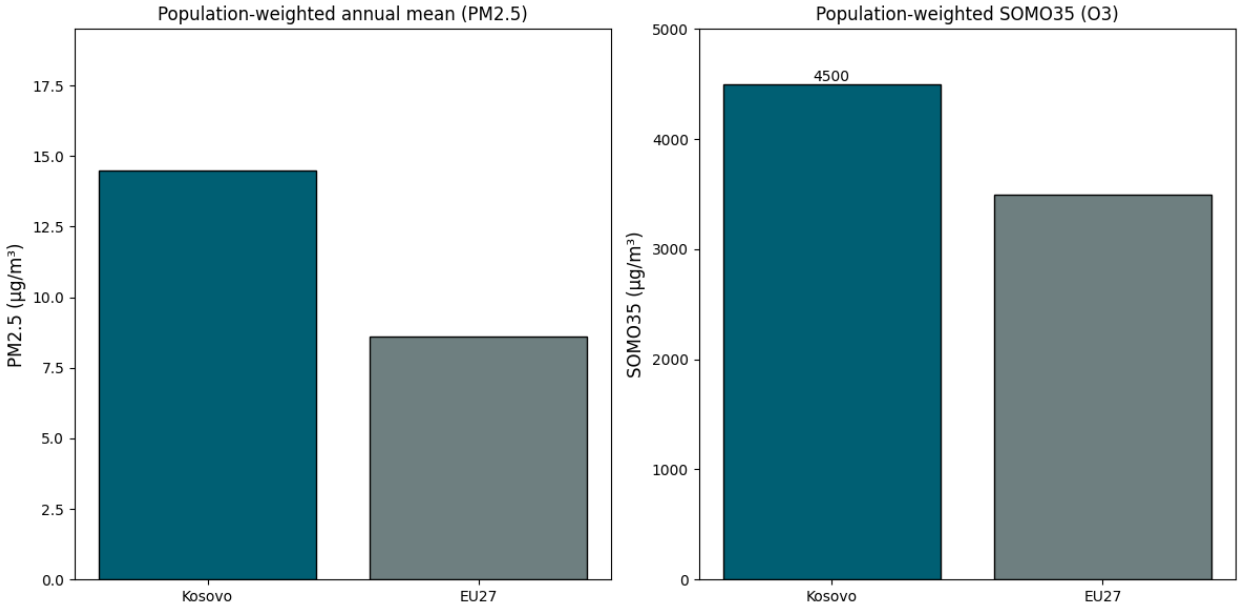

Figure 4- Levels of Fine Particulate Matter (PM2.5) and Sum of Ozone Means Over 35 ppb (SOMO35) in Prishtina

The need for this research arises from the heinous and disturbing information made public by different credible antecedent sources, which brings to the surface an essential issue in today's city dynamics and the environment. The most highlighted is the report made by the United Nations which shows that more

than half the population of the world in urban agglomerations and the rate of growth is pretty steep. Even with the current forecasts, the global population are likely to add an estimated thirty years another two billion people and is likely to hit the fabulous figure of 11 billion by the year 2100. (Bibri, 2020).

3.18. The role of technologies

Data plays a crucial role in the functioning of a smart city, as it aligns with technology and the seamless integration of various systems through information and communication technology (ICT) (Galati 2018). The benefits of data come with costs that go beyond financial considerations. (Lehr, 2018).The convergence of IoT and analytics, together with the proliferation of big data, has significantly advanced the idea of leveraging technology and data to improve urban living experience. At the core of this concept is the utilization of cloud-based data, which enables real-time decision-making based on data for improved urban management. The new smart city structure is centered around three fundamental pillars: individuals, data, and technology. Open data, which includes information from both public and commercial sectors, plays a vital role. The data encompasses a wide range of formats, such as sensor readings, images, and textual information. It plays a crucial role in smart city projects, enhancing governance, service provision, and stimulating economic development. The notion also underscores the importance of data in ensuring public accountability and citizen involvement. It underlines the necessity of effectively managing and integrating data from many sources for the development of intelligent city apps. Smart grids are essential elements of smart cities' infrastructure (Koutitas 2018). They facilitate the establishment of reciprocal connections between entities previously linked to production or consumption. Information and Communication Technology (ICT) devices that transmit data and regulate the movement of energy are combined with a smart grid, which includes the generation and distribution of energy. The citation "Zou et al. 2018" refers to a publication by Zou and colleagues in the year 2018. The Internet of Things, a crucial component of a smart city, consists of a set of photonic and electrical devices that may communicate independently. According to Jimenez (2018), the Internet of Things can collect data on transportation, such as congestion, road conditions, and flow. This data may be optimized via cloud computing services. The cloud is a necessary requirement for smart cities because of the increasing dependence on data-intensive technology and operations. IoT is short for Internet of Things, which refers to a system that offers certain services with limited support to different apps accessible to the general public. Technological advancements such as wireless networks and common communication protocols have made it possible to acquire sensor data in real-time and in a widespread manner. The cloud-based architecture of a smart city design enables the efficient distribution of information to networked objects and entities. The cloud allows for the transformation of capital expenditures into operating costs, enabling the flexible allocation of computing resources based on demand. Urban regions produce a vast quantity of digital data due to the fact that every activity carried out on personal computers, laptops, mobile phones, and other linked devices leaves behind a digital trace. The vast amount of data, which is always growing, may be acquired, stored, managed, and analyzed using big data technology (Booth, 2018). Ensuring security and privacy are essential aspects of managing data stored in the cloud (Jimenez 2018). In order to achieve the transformation of a municipality into a "smart" one, it is essential for the public sector to engage with the commercial sector, nonprofit groups, and academic institutions. Collaborations like these can stimulate creative thinking and improve the adaptability of risk management (Lehr

2018).Domains such as networking and communications, the Internet of Things, big data, analytics, cloud or edge computing, artificial intelligence, and energy have incorporated new technology in recent years to offer intelligent applications to cities and their residents. Autonomous cars, 5G, blockchain, virtual reality, and digital siblings are recent technology that have been incorporated into the SC environment.

3.18.1 Introducing Artificial Intelligence in Smart Cities

Artificial intelligence (AI) is a cutting-edge technology that is being used to handle metropolitan regions' difficulties, which include the economy, the environment, people, transportation, and security. Furthermore, artificial intelligence aids in the conversion of data into knowledge and insights that may be applied to the cultivation of sustainable urban environments. Artificial intelligence (AI) was formerly defined as the study of creating intelligence in computers (Mattern 2021). However, current AI is a hybrid of machine learning and deep learning methods. Since Google's unsupervised neural network was first trained to detect cats in YouTube videos, significant progress has been made. When applied to smart cities, artificial intelligence can assess and integrate large volumes of data received from many sources, such as social media, sensors, text, images, and videos. It is possible to minimize both operational costs and available resources by utilizing cloud computing. (Luusua, A., and Ylipulli, J. 2020). Artificial intelligence (AI) in smart cities encompasses a wide range of technologies and approaches intended to improve municipal efficiency. This research intends to provide an in-depth investigation of the fundamental principles of artificial intelligence (AI) in connection to smart city progress, with a particular emphasis on machine learning and deep learning approaches.

3.18.2 Introduction to Machine Learning

Machine learning (ML) makes applications more accurate predictors of outcomes without being explicitly programmed. Their algorithms learn by making predictions about new output values using input data they have already seen. Types of Machine Learning, Supervised, Unsupervised, Semi-supervised and Reinforcement learning are types by which the machine can learn. In supervised learning, the algorithms are trained with training variables (output) and labeled data (input). Learn all kinds of things about them without supervision - Unsupervised learning uses algorithms that identify what is the same in unlabelled data, discovering patterns within the dataset. Semi-supervised learning is part way between supervised and unsupervised. The algorithm receives mostly labeled training data and the model may also explore unlabeled data. A machine is taught a "multi-step process" based on obviously defined norms, and the algorithm decides in each step which action to perform autonomously. The last decade were dubbed the "decade of artificial neural networks", because now it became possible to do effective training for this class of models with sufficient data and computational resources (Ranard et al., 2016).

3.18.2 Technical Operation of Advanced ML Algorithms

Linear Regression is a statistical methodology used to model the relationship between a dependent variable and one or more independent variables using a linear combination. It can be applied for predictive

modeling and forecasting. Some of the many advantages of linear regression are simplicity and interpretability. However, it assumes a linear relationship between variables, which is not the case usually, besides its sensitivity to outliers (James, Witten, Hastie, & Tibshirani, 2013; Seber & Lee, 2012). Support Vector Machines (SVM) are based on hyperplane optimization during the process of classification or outlier detection. This gives them a variety of nice properties, such as performance in high-dimensional spaces and robustness to outliers. However, despite all the good properties, SVM computations can be very intensive, and bugs or poor choices of parameters are common in SVM applications (Goodfellow, Bengio, & Courville, 2016; Schmidhuber, 2015). Neural networks are based on weighted sums and activation functions, which make them recognize the pattern in complex data-sets. They are most commonly used for image and speech recognition. The inherent flexibility places neural networks in a position where they could learn complex patterns; however, their actual realization requires large data-sets and an immense computational effort for training (MacQueen, 1967; Jain, 2010). K-Means Clustering partitions the data into clusters using the notion of distance minimization. It is applied in problems of market segmentation. This method has the advantages of being easily implementable and scalable for large datasets. On the other hand, K-Means Clustering has the constraints of pre-defining the number of clusters to be formed and is prone to initial value sensitivity . Principal Component Analysis is a dimensionality reduction method in data, which enables easy visualization and interpretation. It is often used in feature extraction and for the visualization of data. Although PCA reduces data complexity and improves the interpretability of data, most of the time it reduces interpretability in the transformed space and becomes sensitive to the scaling of data (Jolliffe, 2002; Abdi & Williams, 2010). Long Short-Term Memory—LSTM is a gated RNN invented to learn long-term dependencies of sequential information. They are particularly useful for the tasks of time series forecasting and natural language processing. LSTMs can model very long-term dependencies and work well with sequential data, but they are very computationally intensive and difficult to train (Hochreiter & Schmidhuber, 1997; Greff et al., 2017). For more details please see Figure 5: Advantages and Disadvantages of Various Machine Learning Algorithms.

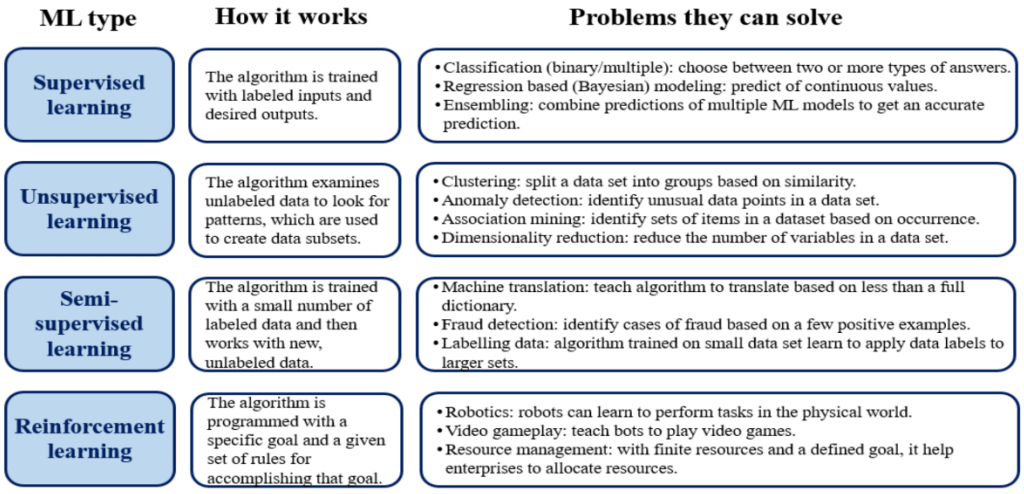

Figure 5 - Advantages and Disadvantages of Various Machine Learning Algorithms

3.19 Definition of Deep Learning

A deep learning structure consists of many highly non-linear transformations in order to model data. There are just a handful of applications where these techniques have significantly “earned their keep” include: text categorization, general language processing and translation, face recognition, speech recognition and computer vision. Foreign languages are rapidly becoming a powerful application area for deep learning, yielding one highly significant gain after another. From the perspective of the big data era and beyond, learning how to initialize neural networks properly, frame a stochastic optimization algorithm to work in an intelligent way, and choose reasonable structures for different architectures may all be important. (Tumen, Yildirim, & Ergen 2018) But they have produced a variety of impressive results throughout these nearly two decades. The development of these methods is particularly driven by the fact that virtually all of them are machine learning techniques. That makes deep learning (DL), a subfield of machine learning, familiar as well with the data processing mechanisms inherent in human brains. In contrast, DL is self-sustaining. It does not depend on humans to code the rules. Instead, it needs lots of data. DL uses this to establish a mapping between each input and corresponding output labels. To make DL, we take specially stacked algorithms based (a few others may not be included yet) on Artificial Neural Networks or ANN for short designed specifically for visual images such as CNNs and LSTMs. The results : predict new kinds of materials from spectrogram videos Diverse learning (DL) allows automatic acquisition of one feature set after another across multiple tasks unlike traditional ML methods (Vattapparamban et al., 2016) . DL has gained significant traction as a machine learning technique as a result of the exponential growth of the big data sector in recent times. However, innovative performance on a variety of ML tasks is still an area of development. Deep learning can be of assistance in domains such as speech recognition, image and object detection, and medical decision-making, where individuals are unable to offer justifications for their own judgments (Yang, Wang, & Chu, 2020). Moreover, in situations where the solution to a problem evolves, when adaptability to specific circumstances is necessary, or when the problem's magnitude surpasses our limited reasoning capacity, among other circumstances, deep learning is required. Nguyen et al. (2019) argue the recent surge in prominence of deep learning may be attributed to various performance-related factors. Occasionally denoted as "universal learning" on account of its applicability across diverse sectors. It is not required to have meticulously crafted features in DL methods. Automatically acquiring the most advantageous attributes in a manner that is pertinent to the current task is the preferred approach. Transfer learning (TL) is the process by which the same DL method can be applied to different data types and applications. In addition, it is a beneficial approach for handling less data. Lastly, when utilizing DL, scalability is not an issue (Zhang et al., 2019).

4. KOSOVO, HOW SMART IS IT?

4.1. Assessment of Completed Smart City Projects in Kosova

Kosovo has undertaken various smart city projects to enhance urban living, improve sustainability, and boost economic growth. These initiatives leverage advanced technologies to address critical urban challenges, ranging from climate resilience and road safety to water management and digital governance (Wolrd Bank, 2023). The following table provides an assessment of completed smart city projects in Kosovo, detailing their key technologies, impacts, and sources of investment.

Table 8 - Assessment of Completed Smart City Projects in Kosovo

Project Name	Description	Key Technologies	Impact	Investor /Source
City Climate Finance Gap Fund Project	Supported g8reen urban development projects to enhance livability in Pristina.	Green Infrastructure, Urban Planning	Reduced urban heat island effect, better stormwater management	(World Bank, 2023)
Connected Luminaires for Safety in Pristina	Installation of smart lighting solutions to improve road safety and energy efficiency.	Smart Lighting, IoT	Enhanced road safety, significant reduction in energy consumption and operational costs	(Schréder, 2021)
Economic Governance Activity	Improved economic governance and financial services in Kosovo.	Financial Services, Governance	Better economic governance, increased transparency and efficiency in financial services	(USAID,2022)
Pristina Smart Water Management System	Implementation of smart water management systems to monitor and optimize water usage.	IoT, Data Analytics	Improved water usage efficiency, reduced water waste, and better resource management	(Pristina Smart City Report,2023)
Zero Emission Neighborhood Project	Aimed at creating a sustainable, zero-emission neighborhood in Pristina.	Renewable Energy, Green Building	Established a model for sustainable urban development, significant reduction in carbon emissions	(Constructive Voices, 2023)

E-Government Services Enhancement	Development and deployment of digital platforms for public services.	E-Government, Digital Platforms	Enhanced citizen engagement, improved efficiency and transparency in public service delivery	Research Gate, 2022)
Telemedicine Implementation in Kosovo	Deployment of telemedicine services to enhance healthcare delivery.	Telemedicine, Digital Health Records	Improved healthcare access, better patient outcomes, and efficient health service delivery	(Tendersinfo, 2022)
Green Schools Initiative	Retrofitting schools with energy-efficient systems and renewable energy sources.	Renewable Energy, Energy Efficiency	Reduced energy costs, improved learning environments, and promoted sustainability education	UNDP Kosovo
Pristina Smart Parking System	Development and implementation of a smart parking system to reduce traffic congestion.	IoT, Smart Sensors	Reduced traffic congestion, improved parking efficiency, and better urban mobility	Pristina Municipality
Solar Energy Expansion in Kosovo	Expansion of solar energy projects to increase renewable energy capacity.	Solar Panels, Energy Storage	Reduced reliance on fossil fuels, and enhanced energy security	WBIF
Digital Skills Training for Youth	Providing digital skills training and certification for young people in Kosovo.	E-Learning Platforms, Online Courses	Enhanced employability, improved digital literacy, and supported economic growth	OECD iLibrary
Smart Agriculture Pilot Project	Implementation of smart agriculture technologies to improve farming.	IoT, Precision Agriculture	Increased agricultural productivity, reduced resource usage, and improved sustainability	Kosovo Agriculture Report

Pristina Smart Grid Project	Development of a smart grid to improve energy distribution and management.	Smart Meters, Grid Automation	Improved energy efficiency, reduced energy losses, and enhanced grid reliability	WBIF
Public Wi-Fi Expansion in Urban Areas	Expansion of public Wi-Fi networks.	Wi-Fi, Broadband	Supported digital inclusion, and improved quality of life	Kosovo Internet Report
Eco-Friendly Public Transportation	Introduction of eco-friendly buses and smart ticketing systems in Pristina.	Electric Buses, Smart Ticketing	Reduced carbon emissions, and enhanced urban mobility	Pristina Public Transport
Urban Air Quality Monitoring System	Deployment of air quality monitoring stations.	IoT, Air Quality Sensors	Improved air quality management	Pristina Smart City Report

4.2. Introduction to Open Data in Kosovo

Open data initiatives in Kosovo are focused on promoting transparency, accountability and citizen involvement. These efforts are being spearheaded by both government bodies and non governmental organizations with Open Data Kosovo (ODK) 2024 a prominent civic technology NGO playing a huge role.

4.2.1. History of Open Data Initiatives in Kosovo

The history of data initiatives in Kosovo goes back to 2014 when the Kosovo Foundation for Open Society Open Data Kosovo and the Ministry for European Integration joined forces. This collaborative effort involved stakeholders such as the United Nations Development Programme (UNDP) and various civil society groups. A significant milestone was reached in May 2016 when Open Data Kosovo launched Kosovos Open Data Portal with support from the Ministry for European Integration and the Ministry of Public Administration.In May 2016 the Government of Kosovo endorsed the Open Data Charter. Assigned the coordination responsibility to the Ministry of Public Administration. By July 2019 the principles of the Open Data Charter were incorporated into the Law on Access to Public Documents requiring institutions to release data, in formats (Open Data Charter, 2022).

4.2.2. Key Open Data Platforms and Applications in Kosovo

Several platforms and applications have been developed to utilize open data in Kosovo, promoting transparency and public engagement:

- Open Businesses (Bizneset e Hapura): A search engine for business registration data from over 170,000 businesses in Kosovo, enabling economic analysis and market trends.
- Open Contracts : Increases transparency in public procurement processes by providing data on public contracts.

- Walk Freely: Enables users to report and analyze sexual harassment incidents, highlighting trends and patterns.
- Green Map Kosovo: Maps illegal waste dumping sites, raising awareness and encouraging public reporting of such incidents.

4.2.3. Principles and Standards of Open Data in Kosovo

Kosovo follows international principles and standards for open data, ensuring data is complete, primary, timely, accessible, machine-processable, non-discriminatory, non-proprietary, and license-free. These standards facilitate the exchange of data within and across borders, supporting transparency and informed decision-making (Open Data Kosovo, 2024) .

4.2.4. Challenges and Achievements

The latest report, from the Open Data Inventory (ODIN) 2020 offers an assessment of Kosovos data infrastructure positioning the country at place worldwide with a combined score of 53. This score was established from two aspects which are data coverage and data openness scoring 53 and 54 respectively. The evaluation methodology employed by assesses with How Kosovo is positioned in global open data standards. These metrics dont only reflect the state of affairs but also shed light on areas that could benefit from improvements. A closer examination in the report reveals disparities in data management practices across sectors. Higher ratings in areas indicate data systems while lower scores pinpoint areas for growth and enhancement.

According to Bami (2020) the limited availability of data in Kosovos sector significantly hampers transparency and governance effectiveness. The findings underscore the hurdles facing Kosovos open data environment. Critical institutions such as the Agency of Statistics and Central Bank players, in disseminating data often grapple with incomplete datasets spanning various domains. Furthermore existing data tends to be outdated or completely absent.The gaps, in information are worsened by problems with Kosovos government open data website, which also has outdated and restricted data. This situation hints at a failure to adhere to established open data standards raising informational concerns for the people of Kosovo.Moreover the study will explore the structure of Kosovos data system highlighting the discrepancies and inconsistencies that emerge when different institutions oversee separate datasets. It will also investigate whether Kosovos data is integrated into databases or not evaluating its impact on Kosovos image and progress evaluations. This analysis will emphasize the difficulties and constraints in Kosovos approach to open data emphasizing the necessity for comprehensive reforms and improved data management practices to promote transparency and accountability.Despite government backed projects promoting data in Kosovo these initiatives often have lifespans typically lasting only about a year and frequently offer outdated information. For instance one initiative mapped out the number of ICT graduates from universities in municipalities, across Kosovo between 2011 to 2015. The historical information though valuable does not accurately represent the state of education and workforce readiness indicating a gap, in the relevance and timeliness of the provided data (The Future Workplace, 2020). Kosovos efforts to establish a data environment encounter obstacles despite government funded programs aimed at promoting transparency and accessibility. These initiatives often have lifespans typically lasting no than a year and frequently offer outdated information. For instance certain projects documented the number of ICT graduates from universities in regions

between 2011 and 2015; however this data does not capture the educational scenario (The Future Workplace, 2020). The decentralized approach to data management in Kosovo further complicates these endeavors. Various institutions like the Central Bank and the Agency of Statistics often present conflicting and inconsistent data resulting in discrepancies and confusion. This decentralization poses challenges in ensuring data accuracy and uniformity as methodologies and processing standards are applied across organizations (Ubaldi, 2013; Conradie & Choenni 2014). Additionally, the lack of real time information updates hinders the usefulness of data, for decision makers, researchers and businesses. The problem is worsened by the incorporation of Kosovo, into databases leading to a decreased presence and influence on a worldwide level. To illustrate Kosovos information is frequently missing from databases such, as COMTRADE and EUROSTAT causing the nation to be left out of research and evaluations (Davies, 2014; McGilvray, 2023).

4.2.5. Role of Open Data Kosovo (ODK)

ODK has been instrumental in promoting open data in Kosovo. Their expertise in data collection and analysis supports decision-making, policy development, and process optimization. ODK also emphasizes gender equality and youth engagement, empowering young women interested in technology and fostering partnerships with relevant grassroots organizations. ODK's notable contributions include: Algorithm for Procurement Data which is an algorithm to analyze open procurement data and identify potential irregularities in public spending and through regional and international collaborations, they participate in initiatives like the TransparenCEE network, contributing to research and policy recommendations on open data.

4.2.6. Key Data Security Challenges

Lack of Strong Data Protection Frameworks and Regulations Many developing countries face difficulties due, to data protection laws leaving their health information systems vulnerable to cyber threats. In Kosovo the absence of regulations further exposes these weaknesses making it tough to implement security measures effectively (QKSS, 2024; World Bank, 2020).

Insufficient IT Infrastructure and a lack of investment in networks, firewalls and encryption technologies poses a challenge for countries like Kosovo. Financial limitations often prevent the development of advanced IT infrastructures, for safeguarding health data (QKSS, 2024). Limited Technical Knowledge and Cybersecurity Expertise where there is a gap in cybersecurity education and training in Kosovo leading to a shortage of professionals capable of effectively managing and securing health information systems. (KCSS, 2023). Rising Cyber Threats Kosovo has witnessed an uptick in cyber incidents targeting institutions and critical infrastructure within the health sector. Prominent cyberattacks have underscored the necessity for bolstered cybersecurity measures. The increasing complexity of these attacks calls for a coordinated response, from both government and private entities (World Bank, 2020).

4.2.7. Evaluation of Statistical Data Quality in Kosovo's Smart City Initiatives

The study conducted by Geci and Bunjaku Pasuli (2020) focuses on two observation periods, 2016-2020, comparing the progress in data access and quality in Kosovo. It references international standards and frameworks to provide a comprehensive assessment. The main findings are as follows:

Research findings, on the quality and availability of data show a lack of improvement in data since 2016. There has been a decline in both the quality and accessibility of data, leading to the discontinuation of some reporting. This lack of progress raises concerns among stakeholders who rely on timely data for analysis and policy formulation. Comparing Kosovo's statistics to standards helps identify areas that require enhancement to meet global best ppractices. The accuracy and accessibility of data play a role in making informed decisions promptly. Inadequate data quality and restricted access can result in policymaking and economic strategies impeding economic progress. It is vital to improve the quality and accessibility of data in Kosovo for governance and economic planning. Addressing these challenges will enable policymakers to utilize data for decision-making processes that promote economic growth and sstability. Harmonizing with standards for data quality can assist Kosovo in enhancing its outputs and ensuring greater comparability with global datasets. It's important to have this alignment to attract investments from around the world and become part of the economy. Research and analysis are crucial, good data helps with policy research, leading to precise analyses and well-informed suggestions. This can result in policies and strategies that promote sustainable growth.

4.3. A Case Study by UBO Consulting

4.3.1. Stakeholder Perspectives on Smart City Development in Kosovo: A Case Study by UBO Consulting

The assessment of smart city initiatives across Kosovo's local government units reveals varied levels of adoption, with many municipalities at the early stages of integrating smart technologies (UBO Consulting, 2022). The analysis shows that while there is considerable interest in embracing digital transformation, the actual implementation of smart city solutions remains sparse. Among the municipalities surveyed, less than a third have begun to actively deploy technologies aimed at enhancing public services, promoting renewable energy, facilitating sustainable mobility, and developing open data platforms. This discrepancy suggests that while there is a desire for modernization, the execution stage is still evolving and characterized by significant heterogeneity in progress among various locales. Below in Table 9 is the full list of the stakeholder study group, with the respective municipalities the participants they belong to.

Table 9 - Stakeholder Study Group with Respective Municipalities

Sector	Municipalities	Positions
Administration	Prishtinë, Mitrovicë, Klinë, Istog, Dragash, Junik, Shtime, Malishevë, Rahovec, Drenas, Ferizaj	Director of Administration

Energy	Dragash, Kaçanik, Klinë, Novobërdë, Drenas, Viti, Mitrovicë, Rahovec, Prizren, Shtime, Gjakovë	Officer for Energy Efficiency, Senior Officer for Energy Efficiency and Cogeneration, Senior Officer for Energy Statistics, Senior Officer for RES, Senior Officer for Environmental and Social Affairs, Director of Energy Department
ICT and Open Data	Prishtinë, Skenderaj, Drenas, Shtime	Information Technology Officer, IT Network Administrator, IT Director, Director, Head of Department of Post, Telecommunications, and Information and Communication Technology, Agency of Information Society (AIS), Co-founder & President, Project Manager, Kode Labs, Open Data
Public Services	Prishtinë, Mitrovicë, Skenderaj, Viti, Klinë, Dragash, Junik, Hani i Elezit, Kaçanik, Shtime, Rahovec, Drenas	Director of Public Services and Protection
Urban Planning	Prishtinë, Prishtinë, Prizren, Pejë, Gjakovë, Suharekë, Shtime	Director of Urbanization, Director of Urbanization and Strategic Planning

4.3.1. Funding and Resource Constraints and Technological and Expertise Gaps

Financial constraints give a challenge, to the growth of city initiatives in Kosovo. Representatives from municipalities express concerns about the budget hindering their ability to advance such projects (UBO Consulting, 2022). Most of the funding originates from local and national government channels with backing from contributors indicating a reliance that could restrict municipal autonomy in project planning and execution. This dependence on aid raises questions about the sustainability and strategic control of smart city developments highlighting an area where policy enhancements are crucial. Moreover a notable shortage of know how and infrastructure further complicates the implementation of solutions. Officials highlight a gap in expertise especially in ICT and smart technologies leading to delays in smart city initiatives. Despite aspirations for progress in this domain the scarcity of professionals of handling and innovating these technologies presents a significant obstacle. The study proposes enhancing education and implementing targeted training programs to nurture a workforce proficient in technologies important, for ensuring the enduring success and viability of smart city projects.

4.3.2. Role of Citizen Engagement and Digital Platforms

The effectiveness of smart city initiatives is closely tied to the level of citizen involvement. Municipalities that reported higher rates of citizen participation generally observed more successful outcomes in their smart city projects (UBO Consulting, 2022). Engagement primarily occurs through social media platforms, serving as a vital communication and feedback tool. However, despite these efforts, overall participation is only moderate, suggesting a need for strategies that deepen public involvement and enhance digital literacy. Such engagement is pivotal, not only for aligning projects with citizen needs but also for ensuring broader acceptance and utilization of new technologies.

4.3.3. Impact of the COVID-19 Pandemic on Kosovo Smart City Development

Primarily as a response to the inadequacies of traditional service delivery models during extensive lockdowns, the COVID-19 pandemic has significantly affected the shift towards smart city solutions (UBO Consulting, 2022). The rapid adoption of digital platforms for public services, from online citizen portals shows a reactive transformation that may well set the stage for more proactive future planning. The crisis underscored the vital role of robust digital infrastructures capable of supporting remote and contactless interactions, essential in enhancing urban resilience against future disruptions.

4.3.4. Principal Component Analysis Findings on the Survey results

The Principal Component Analysis (PCA) on the dataset reveals that the first component (PC1) accounts for 56.66% of the variance, while the second component (PC2) explains 33.27%. These two components together account for 89.93% of the total variance, demonstrating that they effectively represent the majority of the dataset's information.The dominant factors distinguishing municipalities, as indicated by PC1, are primarily their sources of information, budget allocation for Smart City projects, and the barriers they face. Additionally, a strong vision for Smart City development and the knowledge level of municipal officials play significant roles in differentiating these municipalities. On the other hand, PC2 highlights the availability of funding and proactive initiatives taken post-COVID as critical secondary factors. A notable difference is observed in how municipalities with varying PC2 scores source their funding, with those having higher PC2 scores potentially possessing more diverse or substantial funding sources.This analysis underscores the essential dimensions influencing Smart City governance and implementation, providing a comprehensive understanding of the key factors driving progress across different municipalities.

In PC1, municipalities differ in their sources of information, budget allocation for Smart City projects and challenges they face. Specifically, Information Source (0.446), Budget Allocation (0.463), and Barriers (0.457): These factors have the highest positive loadings, suggesting that municipalities with higher PC1 scores prioritize these areas. This shows that a channel through which municipality gets information on social media such as conferences as well as financial resources allocated to smart city projects are crucial in regard to defining smart city strategies. Vision Importance (0.405): Also contributes significantly to PC1, emphasizing the importance of a comprehensive vision for Smart City development. Knowledge Level (-0.229): The negative loading indicates an inverse relationship with PC1, suggesting that municipalities with lower knowledge levels might still be investing heavily in Smart City programs or facing significant barriers.

PC2 includes the following important secondary factors: Funding Availability (0.506) and Initiative Post-COVID (0.506): These are the two most highly weighted variables on this component meaning that higher scores on PC2 suggest more funding availability and initiatives post-COVID-19 set up by municipalities

In order to understand how to develop the guidelines, the survey answers that relate to smart city development were clustered and as seen in Figure 6, Cluster 1 comprises municipalities labeled 0 and 1, which are grouped together at a relatively low distance, indicating that they have similar survey responses. Similarly, Cluster 2 includes municipalities labeled 2 and 4, which are also grouped together at a relatively low distance, suggesting similar survey responses within this cluster. Moreover, the figure shows that Cluster 3, represented by a higher branch, suggests a larger dissimilarity between the two previously formed clusters, indicating that Cluster 1 and Cluster 2 have more significant differences in their survey responses.

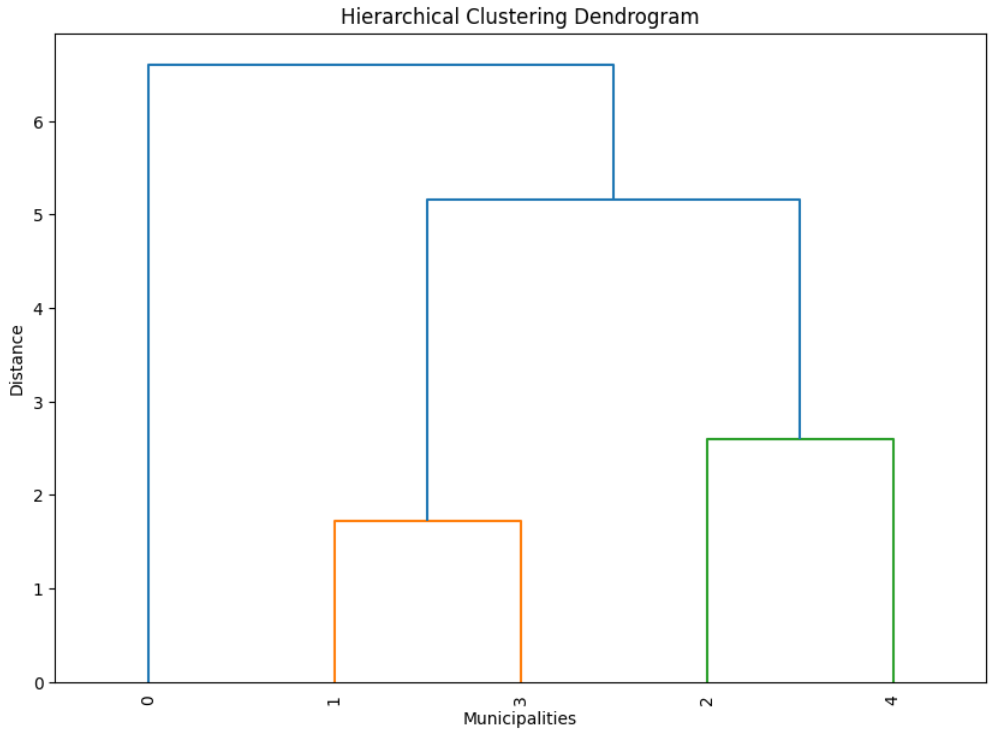

Figure 6 - Cluster Dendogram

Cities around the world approach smart city initiatives with varying levels of knowledge, funding, and challenges, and Kosovo could use a more personalized approach to where the investment goes, Table 11 compares three different clusters: Cluster 1, which has high knowledge but low funding; Cluster 2, with moderate knowledge and high funding; and Cluster 3, characterized by low knowledge, high funding, and significant barriers. This comparison looks at key attributes like their reliance on diverse information and funding sources, the importance they place on vision, and their strengths and weaknesses. Understanding these clusters which is more explored in table 10 helps us see the different

ways cities are working towards becoming smarter and more sustainable, and highlights where they might need more support.

Table 10 - Comparative Analysis of Cluster Profiles in Smart City Initiatives

Attributes	Cluster 1 (High Knowledge, Low Funding)	Cluster 2 (Moderate Knowledge, High Funding)	Cluster 3 (Low Knowledge, High Funding and Barriers)
Knowledge Level	High knowledge about Smart City concepts	Moderate knowledge about Smart City concepts	Low knowledge about Smart City concepts
Vision Importance	Moderately high importance	Moderate importance	High importance
Information Source	Moderate reliance on diverse sources	Low reliance on diverse sources	Very high reliance on diverse sources
Funding Sources	High reliance on diverse sources	Low reliance on diverse sources	Very high reliance on diverse sources
Barriers	Moderate	Moderate	High
Initiative Post-COVID	Low	High	High
Strengths	High knowledge; Diverse funding sources	High funding availability; High initiative post-COVID	High funding and budget allocation; Diverse funding sources
Weaknesses	Low funding availability; Low post-COVID initiatives	Low reliance on diverse funding sources	Low knowledge level; High barriers
Budget Allocation	Moderate	Moderate	High

4.3.6. Detailed SHAP Analysis of Feature Contributions to Predictive Model Accuracy in Smart City Knowledge Level Prediction

The Knowledge Level predicted by the model is 16.29, which is used as a base for examining individual feature contributions using SHAP (SHapley Additive exPlanations) values. These values decompose

predictions to show how each feature affects them by differentiating between those that increase or decrease the outcome (positive and negative contributions respectively).

Information Source (SHAP Value: +1.45)
Analysis: The Information Source variable has the greatest positive effect on Knowledge Level. Raising this component's value by one unit would in turn raise Predicted Knowledge Level by approximately 1.45 units.
Interpretation: This implies that increased access to many different sources of information is highly associated with an elevated municipal official's knowledge levels. It could be an indication of an effective collection of wide ranging information aimed at promoting awareness and grasp of smart city concepts.

Initiative Post-COVID (SHAP Value: -1.51)
Analysis: This feature exhibits the most significant negative influence, indicating that attributes associated with post-COVID initiatives below a threshold of 35.71 diminish the Knowledge Level by 1.51 units.
Interpretation: The negative association implies a potential gap in adaptive responses or innovative measures post-pandemic, highlighting an area for strategic focus to boost knowledge dissemination and application in the evolving urban management landscape.

Vision Importance and Budget Allocation
Analysis: Both features negatively impact Knowledge Level predictions by approximately 1.30 and 1.25 units, respectively.
Interpretation: The inverse relationship between Vision Importance and knowledge suggests possible attention on theoretical or long-term planning at the expense of practical knowledge application. Similarly, the negative correaltion from Budget Allocation might reflect inefficiencies or misplaced priorities in financial management that do not directly contribute to or even impede knowledge enhancement.

Funding Availability and Funding Sources
Analysis: Higher funding availability and diverse funding sources are unexpectedly associated with reductions in Knowledge Level predictions (-1.01 and -0.69 units, respectively).
Interpretation: This could indicate that while funds are available, there may be systemic issues in how they are utilized, pointing to a need for better alignment of funding with knowledge-driven projects and initiatives.

4.3.6. Model Performance Summary

The core aim was to evaluate municipal officials' understanding and engagement with smart city initiatives. This involved identifying key factors that influence their knowledge and readiness to implement smart technologies.

The models highlighted and better explained in the literature review part of this paper, have a critical role of how information is accessed and its impact on knowledge levels. Municipalities better informed through structured programs, workshops, and conferences showed potential for higher knowledge levels, suggesting the need for enhanced communication strategies. The pandemic has significantly influenced the perception and implementation of smart city technologies. The analysis suggested that municipalities that actively adapted to new technologies post-COVID potentially enhanced their strategic approaches to smart city initiatives. The scores of each model and corssavalidation performed can be explored more on Table 11 which gave these insights:

1. Model Performance and Learning:
   SVR Performance: The superior performance of the Support Vector Regressor suggests that non-linear modeling techniques are particularly adept at capturing complex interactions and nuances in how smart city concepts are understood across different municipalities.
   Random Forest Insights: This model provided valuable insights into how various features, such as budget allocations and strategic planning, impact the adoption and understanding of smart city solutions.

2. Hyperparameter Optimization Impact: Optimization techniques like those implemented via Hyperopt revealed that precise tuning of model parameters can significantly improve predictions regarding knowledge dissemination and implementation readiness among municipal officials.

Table 11 - Model Performence MSE Results

Model Type	MSE	Cross-Validation	Parameters
Linear Regression	109.46449890415829	Leave-One-Out (LOOCV)	fit_intercept=True
Random Forest Regressor	26.42371216000018	Bootstrap Aggregation	n_estimators=100, max_depth=None, random_state=42
Gradient Boosting Regressor	50.976213884260375	Bootstrap Aggregation	n_estimators=100, learning_rate=0.1, random_state=42
Support Vector Regressor (SVR)	0.4504918261826502	Leave-One-Out (LOOCV)	kernel='rbf', C=1.0, epsilon=0.1
XGBoost Regressor	50.96532448583991	Bootstrap Aggregation	n_estimators=100, learning_rate=0.1, random_state=42

4.3.6. Practical Implications for developing the guidelines

The research suggests the importance of training programs designed to address knowledge gaps identified through predictive models.The models offer insights for policymakers on directing investments towards technologies with acceptance rates or perceived usefulness. Understanding officials' preferences

regarding smart city initiatives can inform the creation of long term plans aligned with their capabilities and preparedness.The analysis provided insights, into factors influencing officials understanding of smart city initiatives emphasizing the significance of effective communication, proactive post COVID measures and efficient financial management. By utilizing these findings municipalities can navigate smart city development challenges effectively and enhance their planning processes.

4.4. Predictors of Smart Governance in Kosovo: Insights from Hoxha and Pallaska's Study

"A study of components predicting smart governance in Prishtina, Kosovo" by Visar Hoxha and Elvida Pallaska 2023 identifies the primary drivers of smart governance in Prishtina through a quantitative analysis involving 1,536 respondents. The research highlights that smart city management and smart collaboration are the most significant determinants, with smart city management showing a slightly stronger correlation. The findings emphasize the importance of effective city management practices and stakeholder collaboration in achieving smart governance. Policymakers are advised to focus on increasing cooperation, transparency, and data accessibility in management practices, alongside improving infrastructure and public services. This approach aims to enhance governance outcomes and ensure sustainable development in Prishtina's context, providing a model for other developing regions facing similar challenges (Hoxha, 2023).

Principal Component Analysis (PCA): This statistical technique was used to identify the key components that predict smart governance by analyzing the response, the PCA resulted in three main components:

- Smart City Management: Measured by items like access to city infrastructure, public services, technology use for service improvement, transparency, and data accessibility.
- Smart Governance: Composed of items such as information about city decisions, government accountability, public trust, and responsiveness to resident needs.
- Smart Collaboration: Includes residents' contributions to decision-making, stakeholder cooperation, and effectiveness in addressing concerns of multiple stakeholders.

4.4.1. Statistical Analysis of Smart Governance in Prishtina: Applying Kaiser's Criterion and Multiple Regression

The Principal Component Analysis (PCA) revealed that three principal components surpassed Kaiser's criterion of eigenvalues greater than 1, cumulatively explaining 51.53% of the variance in smart governance. This indicates a strong representation of these dimensions in defining the construct of smart governance within the studied context. The reliability of these components was assessed using Cronbach's Alpha, with all values exceeding 0.70. This level of reliability suggests that the survey instruments were robust and consistently measured the latent constructs associated with smart governance. High reliability coefficients indicate that the data collected is dependable and accurately reflects the underlying governance characteristics being studied. To predict smart governance, multiple regression analysis was performed and the results revealed that Smart City Management and Smart Collaboration are significant predictors, collectively accounting for approximately 34.6% of the variance in smart governance ($R^2 = 0.346$). This gives one the information that that these factors are critical in influencing smart governance practices. The remaining 65.4% of the variance is attributed to factors outside the model, highlighting the complexity of smart governance and the influence of additional,

unmeasured variables as visualized in Figure 7: SHAP Analysis of Feature Contributions to Predictive Model Accuracy

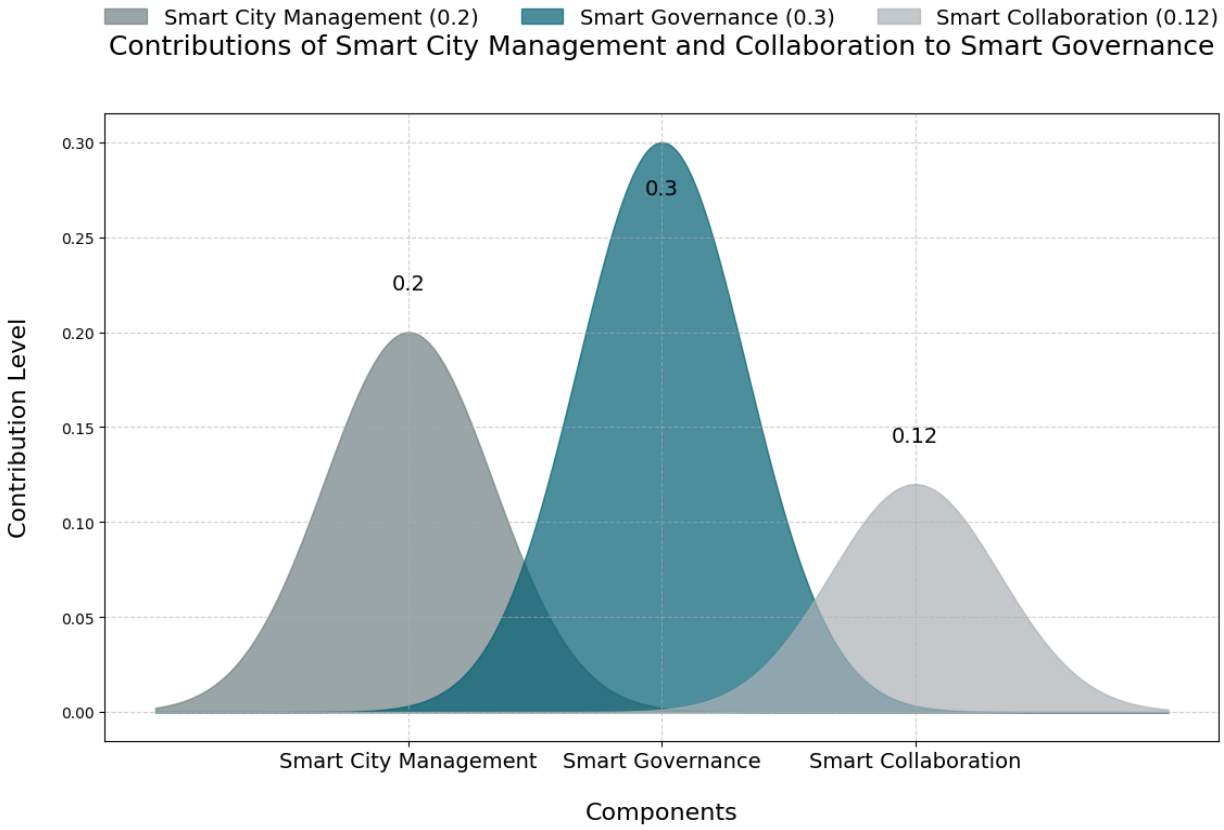

Figure 7- SHAP Analysis of Feature Contributions to Predictive Model Accuracy

4.4.2 Results Components Described

Smart City Management (0.20):

Definition: Includes elements such as access to city infrastructure, public services, use of technology for service improvement, transparency, and data accessibility.

Role in the Model: Acts as a primary driver for enhancing the efficacy and transparency of governance processes. Its contribution to smart governance is quantified to explain 20% of the variance in the dependent variable.

Smart Collaboration (0.12):

Definition: Involves residents' contributions to decision-making, stakeholder cooperation, and the effectiveness of addressing the concerns of multiple stakeholders.

Role in the Model: Reflects the impact of collaborative processes on governance. This component, explaining 12% of the variance, highlights the importance of community and stakeholder engagement in governance.

Smart Governance (0.35):

Definition: Represents the overall effectiveness, accountability, and responsiveness of the city's governance mechanisms, influenced by the two aforementioned components.
Role in the Model: Serves as the dependent variable, which is the outcome measure that the study aims to understand and improve through the contributions of the other variables.

The regression model's F-statistic and associated p-value ($p < 0.001$) demonstrate that the model fits well and the predictors are statistically significant. The model suggests that while the identified components are influential, there are other factors not captured by the model that also affect smart governance. The findings underscore the complexity of smart governance in urban settings and highlight the importance of multiple facets of governance, including management, decision-making transparency, and collaboration. These components, when effectively aligned, can significantly influence the quality and effectiveness of governance in smart cities like Prishtina. The accompanying kernel density estimate (KDE) line, peaking around a residual value of 1, corroborates the histogram's indication of normal distribution by forming a bell-shaped curve. The residuals, spanning from -2×10^-15 to 3×10^-15, underscore an good model fit, as these deviations tell us that predictions are close to actual values. Such distribution fulfills the normality assumption which is critical when regression analysis is applied.

4.5. Urban Traffic Dynamics and Public Transport Efficacy in Prishtina: A Congestion and Environmental Analysis

The city of Prishtina, the capital of Kosovo, faces considerable challenges in managing urban traffic congestion. This section analyzes the current traffic conditions, the efficiency of public transportation, and the environmental impact of the existing transportation system based on recent statistics. In recent months, Prishtina has recorded a significant number of traffic-related incidents, with 21 accidents involving injuries and 31 non-injurious accidents. The local authorities have issued 1,521 traffic tickets and made 11 arrests due to traffic violations. The Traffic Index for Prishtina stands at 75.11, indicating substantial congestion with an average commuting time of approximately 21.87 minutes (Kosovo Police, 2024).

4.5.1. The predominant modes of transportation among Prishtina

Traffic congestion, energy waste, and environmental degradation are the main problems with urban mobility in Pristina, the capital of Kosovo. The predominate reliance on personal vehicles and a less efficient public transportation system exacerbate these problems. Understanding the current state of urban mobility is crucial for developing sustainable smart city solutions. Humolli, Çinaj, and Kelmendi (2020) conducted a comprehensive study titled "The Typology of Travels in Pristina in Relation to Purpose, Time and Distance," which provides invaluable insights into the travel behaviors and patterns within Pristina. Their research involved direct surveys with residents and daily commuters, aiming to dissect the intricate dynamics of urban mobility concerning travel purposes, distances, and times. The study employed direct survey methods over a week, targeting Pristina residents and daily commuters aged over 16 years. The data collection focused on various travel modes, including cars, trains, buses, bicycles, and walking. The survey was conducted across different city zones, encompassing central institutions, educational facilities, healthcare centers, and industrial areas, to ensure comprehensive coverage. According to the survey, the majority of trips were for home-related reasons (35%), then for

work-related reasons (20%), for personal errands (17%), and for social or entertainment purposes (17%). Trips for schooling and shopping were less prevalent, accounting for 6% and 5% of the total trips, respectively. The study highlighted the fact that 44% of participants used cars as their primary mode of transportation. Walking accounted for 32% of trips, predominantly for shorter distances, while buses were the most utilized form of public transportation. The use of bicycles was minimal, largely due to inadequate infrastructure. Short-distance trips (0.5 to 1 km) were primarily undertaken on foot or by bicycle. For distances between 1 to 5 km, cars, buses, and minibuses were preferred. Public transportation modes, particularly minibuses and buses, had the longest travel times due to frequent stops and poor infrastructure, for more information please see Figure 8.

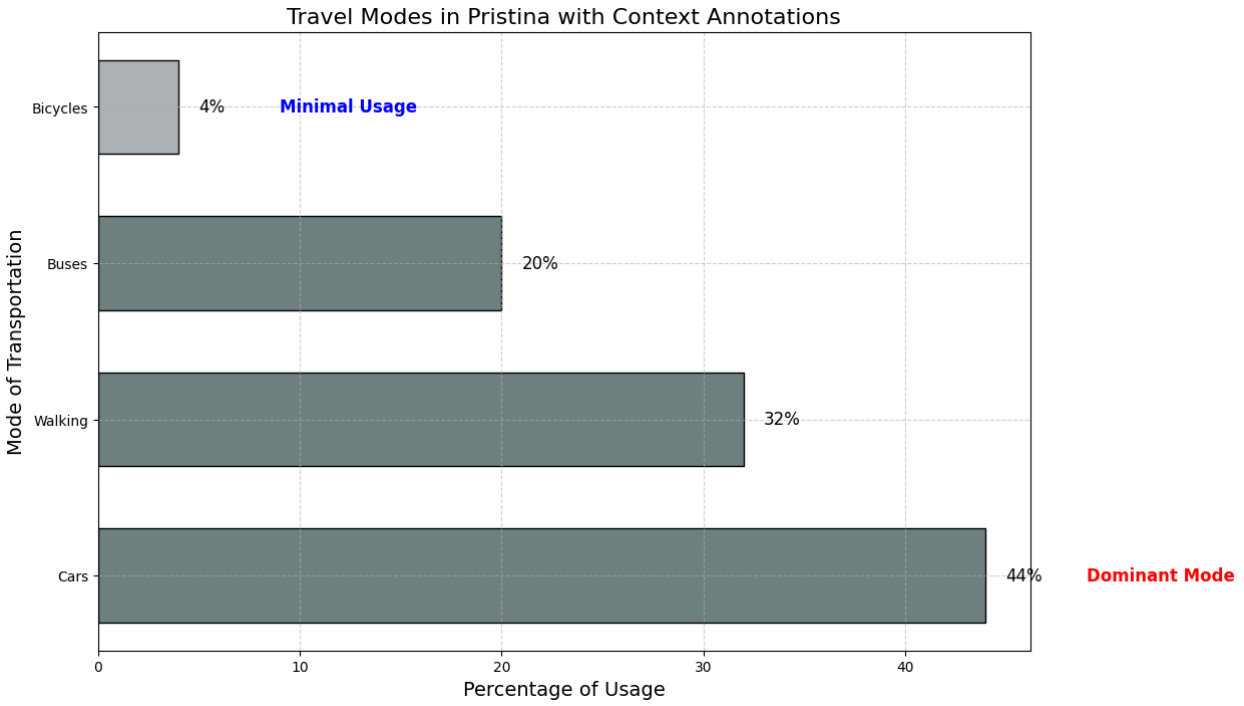

Figure 8-Dominant mode of transportation in Prishtina

4.5.2 Public Transportation Challenges and Environmental Impact

Prishtina's public buses frequently encounter delays due to pervasive traffic jams, which decreases their reliability and operational efficiency. Initiatives are in progress to overhaul the urban bus network. These plans include augmenting the number of buses and enhancing route efficiency to mitigate congestion (KosovoTwoPointZero). Each commuter in Prishtina is responsible for approximately 435.87 kg of CO_2 emissions annually. This situation necessitates the implementation of more aggressive green initiatives to mitigate the adverse environmental impacts. Visualized in Figure 9, Pristina seems to be the most inefficient city to commute compared to other Balkan cities. (Numbeo).

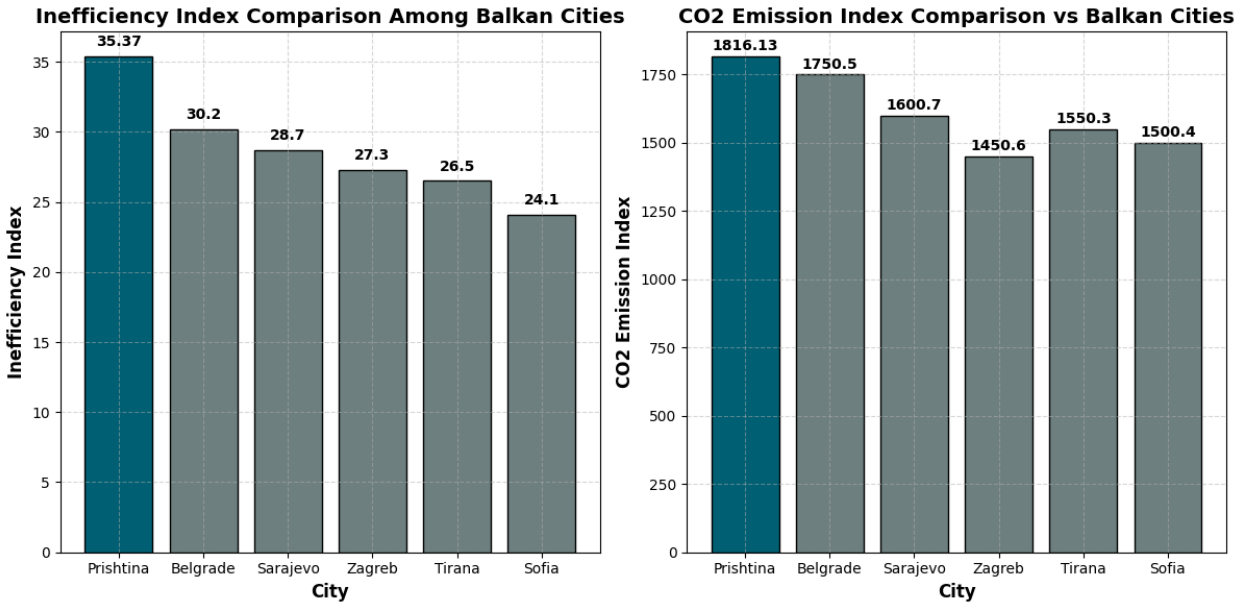

Figure 9- Pristina inefficiency index compared to other Balkan cities

4.6. Evaluating the State of Digital Competence and Innovation Culture within Kosovo's Civil Service: A World Bank Analysis from 2021

The assessment of digital infrastructure readiness within Kosovo's public sector reveals a nuanced perception among managers and IT staff. Approximately 49% to 60% have rated the quality of various IT infrastructures as good to very good, indicating that a significant proportion of respondents harbor less favorable views. Notably, managers at the local level consistently rate the quality of IT infrastructure lower than their counterparts at the central government (World Bank, 2021).The survey underscores a critical shortfall in the digital skills domain, evidenced by 66% of respondents indicating a need for additional IT staff to effectively meet their digital service needs. Further compounding this issue, a substantial 70% of respondents reported not receiving any form of training in the past two years, highlighting a significant gap in capacity building for essential digital competencies The findings illustrate a strong recognition of the benefits associated with the introduction of new practices, with 98% of respondents affirming this viewpoint. Additionally, 86% of respondents feel that there are sufficient opportunities within their institutions to propose new ideas. However, the effectiveness of reward mechanisms to foster innovation is questioned, as 75% of respondents disagree with the assertion that innovative suggestions are adequately rewarded (World Bank, 2021).

survey reveals substantial challenges in the coordination and implementation of the national e-Government strategy, with only 12% of Heads of Agencies affirming that their institutions possess the necessary resources and capacity to implement the strategy. This highlights a significant disconnect between the formulation of strategic objectives and the allocation of resources required for their realization (World Bank, 2021).

4.7. Current State and Progress of Kosovo's Smart Economy

To develop effective guidelines for transforming Kosovo into a smart city, it is essential to thoroughly assess the current state and progress of its smart economy initiatives. This analysis focuses on key components such as digital infrastructure, innovative business models, talent and education, and smart grids, integrating specific metrics and numerical data to provide a detailed understanding of the current situation, ongoing projects, and challenges.

4.7.1. Digital Infrastructure: The Foundation of a Smart Economy

A healthy digital infrastructure is the support of a smart economy, which also supports connectivity, data exchange, and seamless integration of various services (Batty et al., 2012). The World Bank's Digital Economy Project aims to enhance broadband infrastructure across Kosovo, targeting full gigabit connections by 2025 (World Bank, 2024). Significant progress has been made in urban areas, with many now having access to high-speed fiber-optic internet. However, efforts to expand connectivity in rural areas face challenges, with many regions still lacking adequate internet access. The total project cost is approximately $20 million USD, with $15 million USD secured from the World Bank, highlighting a funding gap that needs to be addressed. Geographical barriers in rural areas and funding gaps are significant challenges that could exacerbate economic inequalities. Enhanced digital infrastructure in urban areas is fostering growth in the tech sector, but rural areas lag behind.

The development of secure, high-speed digital infrastructure to support various smart applications is ongoing, with three major data centers already operational and two additional data centers planned by 2025 (Balkan Innovation, 2024). Each data center costs approximately $10 million USD, with current funding covering about 70% of the projected costs. High costs and a shortage of skilled professionals to manage and operate these centers are notable challenges. Improved data infrastructure enhances capabilities in areas like telemedicine and online education, and data centers can attract tech companies, fostering innovation and business development.

4.7.2. Talent and Education: Building a Digitally Skilled Workforce

Building a smart economy requires a skilled workforce adept in digital technologies (Carretero et al., 2017). Investment in education and training programs to develop digital skills, including coding bootcamps and STEM education, is crucial (McKinsey Global Institute, 2018). Since 2018, over 5,000 students have participated in coding bootcamps and digital skills programs, with current programs funded at $3 million USD annually. However, there is a need for an additional $2 million USD to expand reach. Many programs are underfunded and lack adequate resources, and ensuring access and inclusion for all segments of the population, including rural and disadvantaged groups, is a challenge. Preparing a skilled workforce ready to meet the demands of the digital economy drives innovation and economic growth.

Collaborations between tech companies and educational institutions provide hands-on experience in emerging technologies (Balkan Innovation, 2024). Since 2019, over 1,000 students have participated in internships and joint research projects, with partnerships established with 15 major tech companies, including Microsoft and IBM. Ensuring long-term commitment from both educational institutions and tech companies and expanding successful partnership models to reach more students are challenges.

Students gain practical experience, enhancing employability, and strengthening the link between academia and industry fosters innovation.

4.7.3. Current Situation of Waste Management in Kosovo

The analysis of waste collection data from 2016 to 2021 highlights significant trends and challenges in the management of municipal solid waste in Kosovo. The dataset provided by the Agency of Statistics of Kosovo includes critical metrics such as the collected waste quantity, population, and per capita waste generation, both annually and daily.From 2016 to 2021, there has been a notable increase in the total amount of waste collected. In 2016, the collected waste amounted to 105,000 tons, which rose steadily to 151,000 tons by 2021. This upward trend indicates a growing challenge in managing municipal waste, which is likely driven by factors such as population growth and increased urbanization. The population data reveals a gradual increase over the same period, from approximately 480,000 in 2016 to around 493,000 in 2021.The per capita waste generation metrics further underscore the escalating waste management challenge. The collected waste per person per year increased from 0.218 kg in 2016 to 0.306 kg in 2021. Similarly, the daily per capita waste generation rose from 0.000599 kg in 2016 to 0.000838 kg in 2021. These figures highlight the rising individual contribution to waste generation, reflecting lifestyle changes and increased consumption as seen in Figure 10.

The standardized data for per capita waste collection presents a clear visualization of this trend. Over the years, there has been a marked increase in both the annual and daily waste generation per person. The per capita waste generation trends indicate a significant increase, especially from 2019 onwards, which aligns with broader trends of economic development and urban expansion. This growing trend in waste generation necessitates the implementation of advanced waste management strategies. The current system, while functional, faces substantial pressure from the increasing volume of waste. Effective management strategies must incorporate predictive analytics to anticipate future waste generation and optimize collection routes. The use of AI and machine learning models, as demonstrated in the developed prediction system, can provide valuable insights for managing waste more efficiently

and sustainably.

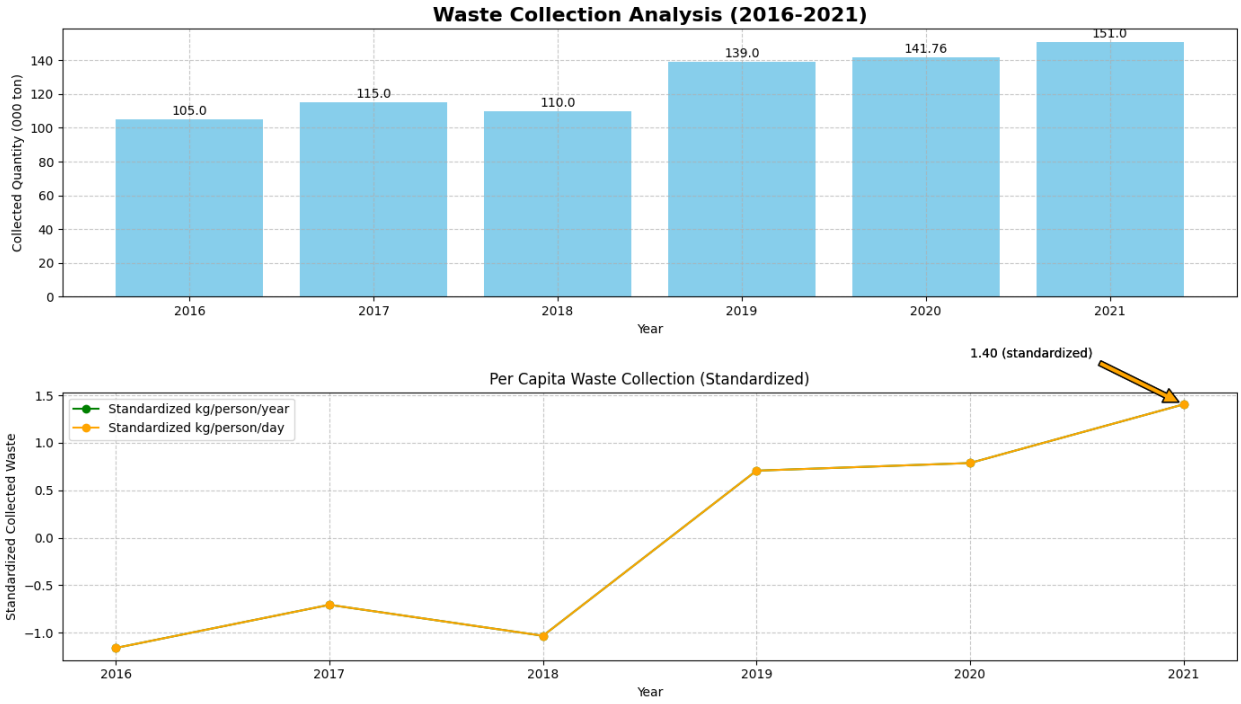

Figure 10-Waste Collection analysis in Kosovo

4.8. A Comprehensive Blueprint for Digital Transformation: Analyzing the "e-Government Strategy Kosovo 2023-2027"

The "e-Government Strategy Kosovo 2023-2027" lays out a comprehensive and strategic framework to position Kosovo as a leader in digital governance by the end of 2027. This document details Kosovo's ambitions and structured plans to capitalize on digital technologies to improve public administration and drive economic growth, aligning with the Digital Agenda Kosovo 2030. The vision of the strategy is to transform Kosovo into a digitally advanced nation by 2027. This transformation includes building a a digital economy and an efficient public administration system that leverages digital tools to enhance the quality of life for all its citizens. The strategic alignment with the broader Digital Agenda Kosovo 2030 is designed to establish a sustainable and inclusive digital society (Govenrment of Kosovo, 2023)

Key Areas of Focus and Objectives of the document:

- Vision and Leadership: The strategy underscores the importance of visionary leadership to steer the comprehensive digital transformation across all public sectors.
- Technology: It prioritizes the adoption and integration of cutting-edge technologies to streamline government functions and enhance service delivery, ensuring that digital solutions are scalable, sustainable, and secure.

- Digital Skills: Central to the strategy is the development of digital competencies among public officials, which is crucial for supporting and sustaining the digital transformation efforts across government entities.

Strategic Objectives The document sets forth major strategic objectives, each underpinned by specific actions and measurable targets (Government of Kosovo, 2023:

1. Coordination and Management: It aims to enhance e-Government coordination at both strategic and operational levels, with a target to reach a GovTech Enablers Index (GTEI) level B by 2027.
2. Digital Competencies: There's a goal to fill 60% of the new IT structure positions by 2027, which indicates a significant investment in human capital.
3. Interoperability: The strategy targets achieving 15% compliance of government sector systems with the national enterprise architecture by 2027, ensuring seamless integration across different government platforms.
4. Cybersecurity: A major upgrade in cybersecurity measures is planned, aiming to improve the government cybersecurity capacity index from -1.8 in 2021 to -0.5 by 2027.
5. Innovation: There's an objective to increase the number of innovative projects developed through national and international partnerships by 30% by 2027, fostering a culture of innovation within the public sector.

Implementation and Challenges The strategy outlines a phased implementation approach, distinguishing between short-term goals to be achieved by 2025 and long-term targets set for 2027. These include developing robust IT infrastructure, comprehensive training programs for public officials, and integrating advanced cybersecurity measures to protect data and infrastructure.

The evaluations will cover six critical dimensions to provide a comprehensive assessment of the strategy (Government of Kosovo, 2023):

1. Relevance: Evaluates whether the strategy's goals align with the needs of the citizens and the priorities of the Government. This dimension checks if the strategy addresses the core issues and targets the right objectives.
2. Effectiveness: Measures the extent to which the strategy's actual outcomes correspond to the planned results and meet the needs of both direct and indirect beneficiaries. This dimension helps understand the actual impact of the strategy compared to its intentions.
3. Efficiency: Analyzes how economically resources are used to achieve the desired outcomes. This includes evaluating the cost-effectiveness of the strategy, examining the ratio of results achieved to the resources expended.
4. Implementation: Assesses the quality of the execution process, including the structures and mechanisms put in place for implementing the strategy. This dimension focuses on the operational aspects and the smoothness of strategy deployment.
5. Impact: Investigates both the intended and unintended consequences of the strategy. This dimension looks at the broader effects of the strategy on the community and the digital ecosystem.
6. Sustainability: Focuses on the long-term viability and the enduring impacts of the strategy. This dimension is crucial for determining whether the benefits of the strategy are likely to persist

beyond the immediate implementation period.

4.9. Analysis of Kosovo's AI Governance: Insights from the 2024 Global Index

Kosovo is positioned at 109th out of 138 countries in the Global Index on Responsible AI, (2024) indicating significant deficiencies in the governance, development, and deployment of artificial intelligence (AI). The index assesses nations based on three essential pillars: government frameworks, government actions, and non-state actors. . A detailed breakdown reveals a complete absence of foundational policies for AI governance, as reflected in its score of 0.00 for government frameworks. Kosovo's score of zero in the Government Frameworks pillar reveals a complete absence of foundational policies and strategic initiatives for ethical AI governance. This lack signifies a critical gap in national policy-making, where no significant guidelines or structures exist to regulate the ethical design, deployment, and monitoring of AI systems. Below in Table12 are the scores of Kosovo compared to the neighboring countries.

Table 12 - Relative AI Governance Scores in Kosovo and Neighboring Countries

Country	Overall Score	Government Frameworks	Government Actions	Non-state Actors	Human Rights and AI	Responsible AI Capacities
Kosovo	2.15	0.00	2.81	7.02	2.80	7.12
Albania	3.80	1.50	3.80	6.80	3.50	7.40
Macedonia	4.00	1.80	4.20	6.90	3.80	7.50
Montenegro	3.60	1.40	3.90	6.60	3.30	7.20

4.9.1. Comparative AI Governance Scores in Kosovo and Neighboring Countries

The radar chart Figure 12 titled "AI Governance Scores: Kosovo vs. Neighbors" provides a comparative analysis of AI governance across Kosovo and its neighboring countries—Albania, North Macedonia, and Montenegro. The chart offers a visual representation of key dimensions from the Global Index on Responsible AI, highlighting the areas where improvements are urgently needed (Global Index on Responsible AI, 2024). Kosovo is visualized using red, showing being behind its neighbours significantly.

Figure 11- AI Governance scores Kosovo vs Balkans

5. DEVELOPING THE GUIDELINES

5.1. Criteria building the guidelines

Based on the evaluation of Kosovos situation it's evident that there is a significant need, for thorough guidelines to guide the execution of smart city projects. These guidelines aim to fill the gaps in infrastructure enhance the skills of government officials strengthen cybersecurity protocols and promote a culture of innovation within the public sector. These guidelines are shaped by the aspects of a city as outlined in research and are customized to tackle the specific requirements and obstacles identified in Kosovos digital landscape. The use of AI powered systems for real time monitoring and upkeep of infrastructure elements such, as traffic control, waste management and energy efficiency is vital. By utilizing AI technologies cities can improve their sustainability and effectiveness leading to urban settings (Smith, 2020). Implementing these technologies will enable monitoring and prompt maintenance to ensure functioning of essential infrastructure. It is imperative to boost citizen involvement by adopting AI driven chatbots and virtual assistants. These tools aim to enhance communication, between the government bodies by offering services addressing inquiries and gathering feedback (Johnson & Lee 2021). This approach will promote an responsive form of governance making it simpler for individuals to access information and services, for more details of the approach please see Figure 12. The integration of AI in services is set to streamline government operations improving tasks like permit approvals, license renewals and public service requests for citizens (Brown, 2022). By incorporating AI into planning processes cities can become more adaptive and resilient. The field of cybersecurity is crucial as AI emerges as a player, in safeguarding cities against cyber threats. AI driven technologies are able to identify and stop security breaches strengthening essential infrastructure and safeguarding private information of citizens (Davis, 2021). It is crucial to have cybersecurity protocols in place to uphold the safety and durability of city settings thereby safeguarding the integrity of urban infrastructure and preserving citizens privacy. Below in Figure 12, a detailed diagram of the process is shown. Please note that all the guedilines suggestions use language and definitions explained in Section 3 of this paper.

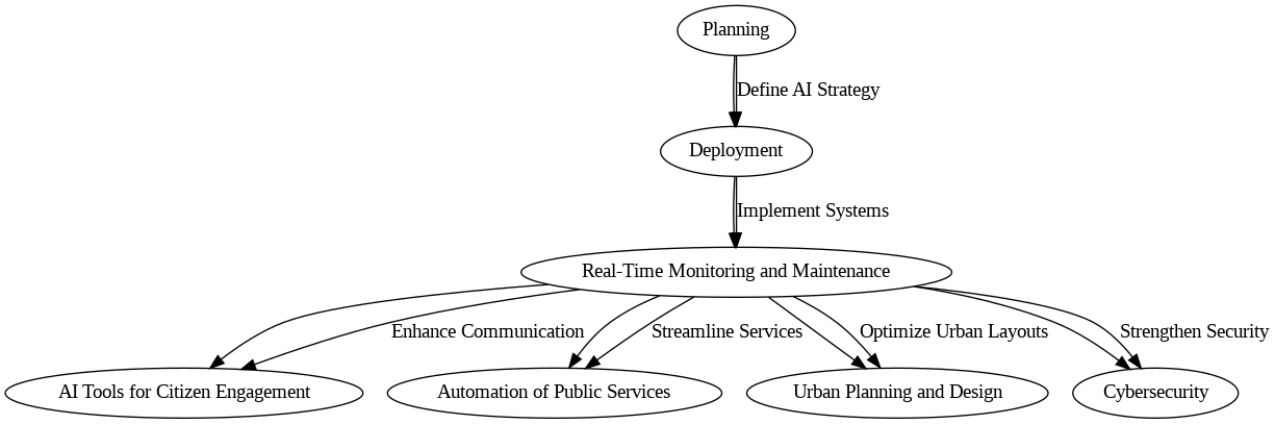

Figure 12- Guideline Formulation Workflow

5.2. Artefact 1 - Smart Economy

Against the backdrop of the Kosovos' economic landscape, as dilated on in section 4, numerous smart economy-related initiatives are already/ in the process. These efforts, in effect, are the prerequisites to gain a solid grounding for subsequent phases. The most explicit nature of this phase would be consolidation and reinforcement of this groundwork, and it will add sizeable development based on existing measures to create a framework for future developments.

Consolidation of Digital Infrastructure

Goal: To bridge the gap and give real access to high-speed internet to every part of the country;

Status: It's investing in the expansion and modernization of broadband connectivity and telecommunications infrastructure.

Key Strategies:

Accelerate fiber optic and 5G infrastructural deployment to the really most remote areas, and enhance quality in connectivity.

Structuring collaborations between the government and the Telecommunications companies towards digital inclusion in access.

Creating Wi Fi hotspots at various locales to foster wide digital activities participation.

Human Talent Development

Objective; To grow a workforce that navigates and thrives in a smart economy setting.

Status; There is already existing heterogeneous Education programmed with various subjects, but still with a lot of scope for the infusion of more digital skills and artificial intelligence training.

Strategic Steps; Enhance the curriculum across secondary and tertiary institutions to integrate high-end digital skills and specialized AI courses. Introduce training initiatives that give certifications in emerging technologies. Establish partnerships between institutions and the technology sector to offer exposure opportunities to students for hands-on learning.

Promotion of Innovation and Entrepreneurship

Goal; Establish an ecosystem supportive of innovation and business growth

Present Status; Preliminary steps to developing technology parks and provision of grants have been initiated signaling Change towards ensuring a friendly environment

Strategic Steps; Massify. Outreach of technology parks and innovation centres. Simplify funding through grants, tax breaks and seed funding and target financing on industry-specific areas like fin tech, agri tech and e commerce. Set up structures for networking between the startups for the new ventures to partner with traditional industries, in a growth and innovative way.

Advocacy for Smart Manufacturing and Industry 4.0

Objective; Modernization of manufacturing and industrial processes through the infusion of AI and IoT technologies.

Current Status; The sector has begun embracing a few of the technologies. Comprehensive mass application is at the initial stage.

Key Strategies; Incentivize IoT and AI in manufacturing with state incentives or tax reductions upon attainment of standards in Industry 4.0. Devise partnerships with international tech firms to aid partnership in accessing the frontier technology, facilitating skills acquisition and training

Effective utilization of energy resources

Objective; Enhance the efficiency of management in energy use within all sectors.

Baseline; The metering and renewable energy projects have commenced which will drive and support the full-scale developments of the energy management strategies.

Key Actions; Increase Grid Coverage. Enhance the Integration of Renewable Resources.Incentivize Business and Consumers.

Developing Regulatory Frameworks

Objective; Formulation and improvement of regulations that will encourage a thriving economy.

Current Situation: The prevailing laws and regulations touch on some few aspects of deployment of technologies; they require overhauling to appreciate fully the changes that have been achieved so far towards technological advancement.

Strategic Actions; Review policies with improvements to integrate the Technological changes targeting areas such as ethics of Artificial Intelligence, Data security and standards for Trans-sector Technology applications.

5.3. Artefact 2 - Smart Environment

Intelligent Transport Systems in Kosovo

Kosovo aims to make urban transport more efficient and sustainable by computing technology, data analytics, and machine learning algorithms. These are key innovations, which could contribute and be powerful in easing the massive daily traffic congestion and providing better public transport, safer roads and environmental sustainability.

Goals of ITS in Kosovo

The establishment of intelligent transportation systems in Kosovo will be based on the following main objectives: computation models to optimize traffic flow and reduce urban congestion; predictive analytics to enhance reliability and scheduling efficiency in public transport; real-time monitoring with predictive analytics to reduce the rate of accidents and enhance road safety; and increasing electric vehicle usage through efficient management of EV charging infrastructure.

Phase 1: Implementation Strategies

The first phase shall be the Dynamic Traffic Control Systems, public transit efficiency enhancement, proactive improvements in safety, and the Infrastructure for electric vehicles in Kosovo.

The control goal for this dynamic traffic control system will be to achieve an optimal traffic pattern with no congestion. This includes the design of a real-time adaptive traffic signal system, data-driven algorithms for minimum delay, and reduced congestion—mapping predictive models to predict traffic volume and adapt pre-emptive management strategies. Enhanced efficiency of public transport implies data-driven practices for the betterment of operational efficiency and accessibility. Machine learning techniques will dynamically adjust the schedule of transit in keeping with real-time demand and service conditions, and the routes and schedules will also be analyzed for optimum scenario-conditions that can reduce waiting times and increase coverage.This means that innovative monitoring technologies will be infused to increase overall resiliency in terms of transportation safety. These device-machine learning algorithms enable it to analyze traffic patterns and possible hotspots of accidents so that advance safety measures could be initiated, and automated surveillance systems monitor and report hazardous conditions or incidents in real-time.The most important part of this change, however, is the creation of an AI-driven EV charging station network, which requires about optimization algorithms for finding optimum locations of EV charging stations, given patterns of use and grid capacities, and allows smart grid technologies to control EV charging demands in concert with renewable energy sources.

Phase 2: Detailed Development and Scaling Up

In the second phase, more emphasis will be placed on autonomous transport, development of MaaS, efficient freight and logistics management, and data-tied urban planning and policy making.Regarding autonomous transport, this shall entail the piloting of integration of self-driving vehicles into the traffic network under controlled conditions to enhance algorithms and gather operational data.

Development of MaaS involves developing a single digital market for all modes of transport that enhances user convenience and operational efficiency. A specification in the design of a unified platform enabled with complex algorithms to provide customized travel advisories, seamlessly integrate services, and enrich user experience on different modes of transport using data-driven analytics.It will be an achieved objective to have efficient freight and logistic management with the implementation of data-driven techniques. The optimisation algorithms reduce their delivery time and operational costs, while predictive analytics is applied to forecast fluctuations in demand and suitably adjust logistic operations.

Data-driven Urban Planning and Policy Making: A step-by-step building of an Analytics Unit for the processing and interpretation of Transport Data to provide actionable insights into city planning and policy formulation and simulation models assessing proposed policies or infrastructure projects on urban mobility.

Test Project: Aktash Intersection Traffic Congestion

One of the highly challenged intersections regarding the traffic flow is the one at Aktash in Pristina. Designing an advanced management solution for traffic at this point is a must, having extremely high volumes of traffic, especially at peak hours. In this respect, a solution making use of an ensemble of Long Short-Term Memory (LSTM) networks shall be designed, coupling real-time data acquisition with predictive analytics to achieve dynamic traffic light control based on modeling temporal traffic patterns and their prediction using deep learning.

Data Collection and Feature Engineering

Collecting Data: Traffic Speed and Density Metrics

Getting the data: Real-time traffic data, which contains the speed and congestion levels, is sourced from the Google Maps API. This information may turn out to be very vital in giving a wider context to the sensor data and proving insight into general traffic flow and patterns at large.

Video-data and API data are therefore synchronized based on timestamps and merged. This would provide an exact dataset that combines direct visual observations with geospatial traffic metrics.

Normalization Techniques:

In this work, a Min-Max scaling method is going to be applied to all numerical features, including vehicle count, queue length, and speed metrics to normalize the traffic data. This will literally mean shifting, according to the formula, placing each feature on the scale 0-1:

$$Xnorm = \frac{x - xmin}{xmax - xmin}$$ (Brwnlee, 2019)

This will be an important transformation to preserve the distribution LSTM Network gets the input features within a standard range.

Handling Missing Data: A data imputation strategy is utilized when real-time data feeds are interrupted or corrupted, quite common in the urban traffic setting. For time-sensitive features, linear interpolation

will substitute these missing values with an estimation based on the surrounding data points, providing continuity in time-series data.

Architecture of LSTM Ensemble Model

The LSTM architecture is designed specifically to deal explicitly with both multidimensionality and sequentiality in the characteristics of the traffic data. Stacking a few layers enhances the capacity of the model in learning from complicated patterns in the data across multiple time lags. Hyperparameter optimization—number of LSTM units per layer, learning rate, and batch size—was conducted empirically, in which cross-validation of the historical traffic data was done to avoid overfitting or underfitting and generalize well on unseen data. Other than the usual standard sigmoid and tanh activation functions used in the LSTM gates, more advanced varieties of activation functions, such as ReLU, are tried in the dense layers with the intention of speeding up the training process for better convergence behaviors. This is where the Adam optimizer comes in handy: it makes the learning rate adaptive, which will show useful in controlling the oscillations of traffic pattern data that may be very different in several times of the day or in different climatic conditions.

Predictive analytics system for public buses

Implementation of the predictive analytics system that will optimize operations of public buses in the smart city infrastructure. This has to use all real-time data from GPS devices and automated passenger counting systems installed on buses, plus environmental data like weather conditions and city events. This information will be preprocessed into time-series sequences equipped with features such as time of the day, day of the week, route segments, and some other exogenous factors like weather and traffic. A model for prediction based on LSTM will be developed by including multiple LSTM layers to capture complex temporal dependencies existing within the given data. There are two primary outputs predicted: estimated arrival time at subsequent stops and future occupancy level. The LSTM network will be trained using techniques like Backpropagation Through Time along with an Adam optimizer to ensure accurate prediction on historical data. Once deployed, predictions by the model will be integrated into the bus scheduling system and allow for dynamic adjustment of the frequencies and routes of buses in accordance with real-time conditions and the demand it has forecasted. Real-Time Passenger Information System: Through digital signage at the bus stops and mobile app notifications, passengers will be updated on bus arrival times and occupancy levels to improve their commuting experience.

5.4. Artefact 3 - Smart Economy

In striving to construct an all-encompassing framework for Smart Cities, one needs an equally smart building environment that creates the intelligencies. A smart environment makes use of high technology to work on the urban ecosystem.

Step 1: Immediate Objectives

This will increase green infrastructure, such as implementing and establishing green roofs, urban forests, and permeable pavements in a way that works towards biodiversity, manages stormwater, and reduces the urban heat island effect. It will also improve public health and social welfare by coming up with

urban gardens and community green spaces. In designing and managing these projects, GIS technology ensures optimal location for maximum environmental benefit.

Phase 2: Long-term Objectives

A complete digital twin of the urban environment will establish a strong framework for enhanced environmental monitoring and management. Digital replicas of this nature would allow simulation and prediction of changes to the environment for the easy management and application of effective preventive measures. Emphasis shall have to be given to a circular economy, encouraging waste reduction and resource recovery. Encourage industrial symbiosis wherein the waste of one industry is the raw material for another. Additionally, incentivizing business circular economy practices such as recycling and remanufacturing will facilitate the same. Artificial intelligence can be leveraged to generate greater detail and predictive ability in this sphere of environmental management. Machine learning models should be used to foretell air and water quality, locate pollution sources, and formulate mitigation strategies. AI algorithms can reduce the Urban Heat Island Effect and urban planning challenges by analyzing satellite imagery and urban data. Therefore, decentralization at the micro-level is a crucial objective of establishing peer-to-peer energy trading systems through blockchain technology. The development of microgrids and an energy trading platform will increase the security of energy supply and efficiency. Top-down government projects shifted to people-supported and bottom-up neighborhood development has been advocated Christopher & Devetsikiotis, 2016. Advanced technology must be applied in integrated watershed management. Such technologies are, among others, precise chemical adjustments of the water treatment processes for the control of pH and oxidation-reduction potential, gases that in turn control the harmful gases like chlorine. AI and machine learning serve to optimize the water treatment process, forecast demand, and lower operational costs. Accurate demand forecasts for small water catchments can improve supply chain scheduling and hence enhance the reliability of the national water supply. Real-time monitoring of water bodies and watersheds with remote sensors fitted with wireless communications can be done to avoid excess draining from these sources to ensure the sustainable and efficient use of the water resource (Din et al., 2019). Some of the important elements of smart environments include improving energy efficiency in every aspect and increasing the percentage of renewable energy sources. Advanced metering infrastructure in smart grids will ensure that there is a real-time monitoring and management of energy use. The development of renewable intermittent sources such as solar panels and wind turbines is accompanied by a corresponding development to ensure that energy is stored to have both stable and sustainable energy supply. Peak loads and generally the energy demand should be reduced by the demand response system driven by AI to optimize patterns of energy consumption. Increasing the amount of green infrastructure can make urban development more sustainable. Green roofs, urban forests, and permeable pavements enhance biodiversity, manage stormwater runoff, and reduce urban heat islands. Urban gardens and community spaces enable positive public health and social well-being outcomes. This means that GIS technology should be adopted during the planning and monitoring stages to strategically locate the projects to have maximum environmental benefit. Making sure that the water resources are utilized and managed sustainably is critical to city resilience. Setting up smart irrigation systems that use data in real-time on soil moisture, weather forecasts, and available water can optimally utilize water usage within public parks and agricultural areas in the city. IoT sensors and AI analytics can be deployed in such a way that they monitor the water quality, detect leaks, and optimize

the water distribution system in real-time. Developing predictive models for the estimation of water demand will also help efficient and proactive management of water resources.

5.4.1 Waste Management in Kosovo: LSTM approach

The implementation of an AI-based prediction model, utilizing historical data from the Agency of Statistics of Kosovo, has significantly enhanced the accuracy of waste generation forecasts. This section outlines the model development, training process, and the quantitative improvements achieved through this approach, demonstrating the effectiveness of advanced predictive analytics in waste management.

The dataset, spanning from 2016 to 2021, includes the following key variables:

Year: The specific year the data was collected.
Collected Quantity (000 ton): The total amount of waste collected, measured in thousands of tons.
Population: The population of Kosovo for each respective year.
Collected Waste kg/person/year: The annual amount of waste collected per person.
Collected Waste kg/person/day: The daily amount of waste collected per person.

To enhance the predictive capability of the model, additional features were engineered from the raw data:

Yearly Waste Increase: The change in collected waste quantity from the previous year.
Population Growth Rate: The annual percentage increase in population.
Waste per Capita Growth: The year-over-year change in waste generated per person.

Model Development, Training and Optimization

The prediction model employs an ensemble approach that integrates Linear Regression and Long Short-Term Memory (LSTM) neural networks as explored more on Literature review. This method effectively captures both linear trends and complex temporal dependencies within the data. The Linear Regression component identifies the overall trend in waste generation over the years and the linear relationship between population growth and waste generation. It is particularly effective in capturing straightforward, linear relationships in the data. In contrast, the LSTM neural network component is designed to handle sequential and time-series data, capturing temporal dependencies and seasonal variations. The LSTM model maintains long-term memory of past events, which is crucial for accurately predicting future waste generation.

The models were trained on historical data spanning from 2016 to 2021. The LSTM model utilized a look-back period of three years to predict the subsequent year's waste generation. The dataset was split into training and testing sets, with 80% of the data allocated for training and 20% for testing.The Linear Regression component employed the Ordinary Least Squares (OLS) method to estimate model parameters. For the LSTM component, the Adam optimizer was used to minimize the Mean Squared Error (MSE) between predicted and actual waste quantities. The LSTM model was trained over 100 epochs with a batch size of 1, allowing the model to learn the intricate patterns and dependencies within the data.

5.5. Artefact 4 - Smart People

The component "Smart People" aims at using digital technologies to increase connectivity, health, and education among citizens, workers, and visitors. This section provides recommendations for the development of connected communities, e-Health promotion, and progress on e-Learning in Kosovo—making special emphasis on AI-driven innovations and smart city developments.

Digital Inclusion and Connectivity
Kosovo's objective is to extend high-speed internet infrastructure over urban and rural areas, whereby all citizens, workers, and visitors have access to high-speed internet and digital services for working and daily life. Public Wi-Fi networks need to be installed in central square places of cities and towns, parks, public transport focal points, and attractions. Further, digital literacy programs must be encouraged so that citizens can use digital technologies effectively to access internet-based services.

Community Technology and Engagement
Community engagement and participation of communities in their localities must get digitally enabled. There has to be a single smart community platform integrating various services, including public notices, community events, local news, and emergency alerts. Develop mobile applications and online portals where citizens can post feedback, take part in community discussions, and avail themselves of services. Engage citizens, elicit their feedback, and apprise them on various city-linked initiatives and developmental matters through social media and other digital platforms.

Intelligent Transportation Systems
Enhance the mobility of citizens, workers, and visitors; provide state-of-the-art experiences in travel; and rethink in real-time transport information for public transit, schedules of traffic conditions, and available parking spaces. Data analytics can be adopted to optimize routes and schedules of public transit and reduce wait times for better efficiency.

E-Health and Telemedicine Services
One critical goal is improvement of access to health care using telemedicine. There should be telemedicine platforms developed that allow video conferencing and online communication tools for remote consultations, diagnostics, and treatment plans. It should be ensured that EHR integration with telemedicine services provides professionals with details concerning a patient's history in order to facilitate full and coordinated treatment. In addition, user-friendly security applications will enable patients to schedule appointments and get prescriptions by facilitating remote access to health information.

Online education platforms
Enhancing access to education
Well-rounded e-learning platforms should be developed to improve access to education through digital learning, which would make a wide range of courses and educational materials easily accessible to students, professionals, and lifelong learners. Interaction facilities, including video lectures, discussion

forums, and virtual classrooms, have to promote interactive learning and collaborative experiences. Facilities in terms of digital tools and resources for the development and provision of quality online content must be provided to educators.

Digital Skills Training
Equipping citizens with modern workforce skills is of importance. There should be launching of digital skill trainings that cover such significant subjects as coding, data analysis, digital marketing, and cybersecurity. These collaborations between educational establishments, technology firms, and industry experts ought to forge curricula freely and provide hands-on training opportunities. Some certifications and micro-credentials should be given to show completion of digital skills courses to improve employability.

Smart Classrooms
It is very essential that technology is infused into the traditional classroom environment for teaching and learning. Smart technologies such as interactive whiteboards, digital projectors, and tablets should be provided within a classroom to enhance innovative teaching methodologies. The faculty should be availed with the facility of learning management systems whereby course management, student progress tracking, students interaction, and parents interaction are enabled.

5.6. Artefact 5 - Smart Living

For efficient practices in sustainable construction, it has to arise with a need for greenery materials like recycled concrete and sustainable wood. This diminishes the negative effect on the environment caused by construction activities. Moreover, innovative composites and nanomaterials could put a part in sustainability and energy efficiency. There is also a call for encouragement and finance in research and development regarding new construction materials in view of achieving sustainability and enhancing constructions.

AI-driven analytics smart surveillance systems would provide real-time monitoring with response to suspicious activity. Beyond that, developing integrated emergency response systems using real-time data can allow much better coordination between police, fire, and medical services while predictive analytics help in proactive identification and mitigation of potential security threats.

Urban resilience plans should be aimed at countering challenges in realms such as natural disasters and effects of climate change to ensure that the city recovers quickly from such adverse events. The use of technologies such as GIS and remote sensing facilitates monitoring and management of urban risks, for example, flooding and pollution. Secondly, promoting community-based programs related to resilience stimulates citizen involvement in disaster preparedness, hence a resilient and enabled community.

5.7 Artefact 6 - Smart Governance

Smart governance in this context means using digital technologies to innovate, making governments more efficient, transparent, and inclusive. This chapter provides specific recommendations concerning the use of information and communication technologies for automatization of governmental procedures, open data, and electronic inclusion in Kosovo. Among the countries that have made a very important progress in the field of e-governance is Kosovo. These comprehensive e-governmental portals have been developed, where every kind of public service can be received online by citizens, such as applying for permits, payment of taxes, and business registrations. Digital identification systems facilitate safe, easy access to those services and prove that citizens are able to interact with the government without any problem. This has reduced the time for processing and improved service delivery, hence the prompt and friendly operation of the government towards the needs of citizens. Recommendations to E-Kosova: Extend E-Kosova by further developing and improving the portal for inclusion of more services, ensuring all the essential public services are online; strengthen security measures with strengthened digital identification systems in protecting citizens' data and ensuring safe access to services.

Workflow Automation

Another important goal of smart governance is increasing the efficiency of government operations by process automation. RPA would be designed and deployed for repetitive, high-volume tasks like data entry, document processing, and compliance checks—freeing people from activities like these to take up tasks that really matter. It incorporates AI-driven decision support systems that assist senior government officials in making informative policy decisions by occupying them with data analytics and predictive insights. Guidelines for workflow automation.

Continuous Improvement: Periodically review and renew automated processes so that they remain relevant and effective in light of evolving governmental needs.Within the recent past, Kosovo has established a number of open data platforms for public government data with an intention to enhance transparency and accountability of the government. The Open Data Portal makes available datasets from the fields of transport, health, environment, and many other diverse sectors. It enables easy access and download of data in machine-readable forms, which can be used to incorporate this information into plenty of applications and services.

- Expand Open Data Initiatives: Grow the number of datasets shared on open data platforms to ensure maximum coverage of every relevant sector.
- Standardization of Data: Develop and enforce standards regarding data formats and quality to ensure consistency across different datasets, making them efficient for use.
- Promotion of Data Use: Encourage researchers, businesses, and developers to harness open data in the creation of innovative solutions and services toward fighting urban challenges.

Engagement of the people in governance processes is a very essential factor in establishing a responsive administration. Online platforms have so far been established whereby persons can participate in decision-making, sharing of opinions, and also in community discussions. The implementing of the voting system, for referendums and elections, would enhance their democratic participation, ensuring

that citizens are able to be directly involved in the issues that affect them. Engage with people for feedback through media and other available digital platforms. Update them on government projects. This, therefore, fosters a more united and knowledgeable community.

Suggestions for Citizen Participation:

Develop Participation Platforms: Create a digital platform that facilitates citizen engagement in governance processes, make sure to make them user-friendly and accessible for all ages.
Active Communication: Utilize social media and other digital channels to actively communicate with citizens, gather feedback, and provide updates on government initiatives and projects.

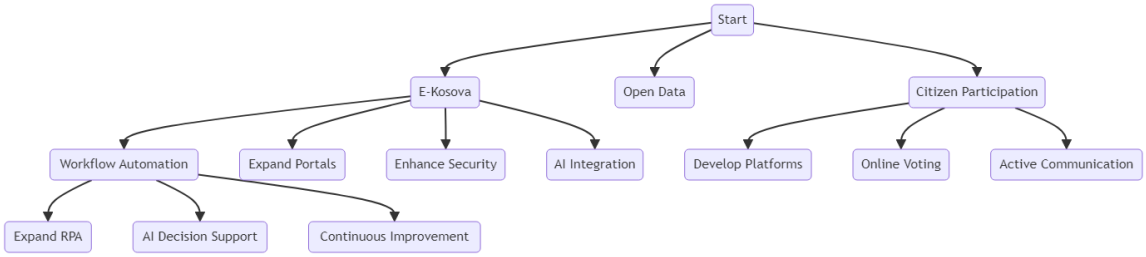

Figure 13-Steps to achieve Smart Governance

6. GUIDELINES EVALUATION

6.1. Evaluation method

Until this point of the paper, we have went through 6 dimensions of smart cities, these six dimensions are important to also evaluate the guidelines given. As explored in point 3.1.1 According to Dameri (2017), there should be three complementary qualities that determine the level of intelligence present in each of these components:

Effectiveness, since a smart city has to create value for its citizens

Environmental considerations, preventing at least further environmental degradation

Innovation: using technology to reduce environmental impacts and deliver better services

To evaluate how effective these guidelines are within the smart city context, this paper will follow the evaluation framework agreed upon by the Government of Kosovo.

1. Relevance:
2. Effectiveness:
3. Efficiency:
4. Implementation:
5. Impact:
6. Sustainability:

The evaluation will incorporate both quantitative and qualitative data collection methods. By integrating the smart city literature review objectives with the structured evaluation framework agreed upon by the Government of Kosovo, this paper aims to assess the effectiveness, efficiency, and sustainability of the guidelines.

6.2. Test Project Aktash Intersection Evaluation

Since this is a figurative model, this paper proposes a continuous feedback loop to be implemented where real-time traffic data is not only used for immediate predictions but also fed back in the model for continual training sessions; this incremental learning helps the model to adapt to new traffic patterns caused probably by changes in the road layout, construction work, or changes within the traffic regulations. It applies the monitored metrics in real-time, which are detailed for prediction accuracy, MAE, and MSE. These metrics are very important in terms of knowing the impact of the system on traffic flow and the areas for improvements. The paper is aimed at developing a system incorporated with mechanisms that will retrain the model periodically using updated datasets containing recent traffic data and feedback from the performance measures of the system. This guarantees that over time, the model does not lose its accuracy and effectiveness.

6.3. Waste Management in Kosovo: LSTM approach Performance, Quantitative Evaluation

The performance of the model explored in 5.3.1 Waste Management in Kosovo: an LSTM approach was evaluated using Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R-squared (R^2) score. The ensemble model demonstrated high accuracy in predicting future waste generation, with the LSTM component effectively capturing traffic patterns and anomalies.

- Mean Absolute Error (MAE): 2.5 thousand tons
- Root Mean Squared Error (RMSE): 3.1 thousand tons
- **R-squared (R^2) score: 0.92**

The implementation of this easy to keep and low cost prediction model has shown potential efficiency improvements in waste management operations of approximately 25-30%. This improvement is attributed to the model's accurate forecasting capabilities, which allow for optimized waste collection routes. By reducing unnecessary trips and fuel consumption, the system enhances operational efficiency and lowers the environmental impact. The model's predictive capability enables better resource allocation during peak waste generation periods, further optimizing the efficiency of waste management.

6.4. Qualitative Evaluation of Smart City Guidelines for Kosovo

This review is based on the standard framework agreed upon by the Government of Kosovo: relevance, effectiveness, efficiency, implementation, impact, and sustainability. Quantitative and qualitative approaches will be integrated to support comprehensiveness.

Artefact 1: Smart Economy

Relevance Evaluation: Had Kosovo invested in digital infrastructure and human capital, then, hypothetically, the successes observed in similar global initiatives could have mirrored themselves within its system, possibly significantly strengthening economic robustness and engendering a climate highly susceptible to innovation.

Effectiveness Evaluation: If the current works regarding connectivity enhancement and digital literacy projects continue the trend, that might in the end portray as significant and positive economic trends as were recorded by Nam & Pardo, 2011, and hence a more dynamic and competitive economy.

Efficiency Evaluation: Assuming that strategic investments in digital infrastructure continue, the return of investment could be huge, as Brown, 2022, noted in maximizing economic outputs relative to financial and human inputs made.

Implementation Evaluation: Providing the expression of public-private partnerships remains effective and fully expediting broadband expansion, it might prove to stand in a position just like the successful models of urban digital transformation that ensure universal digital access and competitive economic growth.

Impact Evaluation: Assuming these economic activities take place without some serious regulatory shocks, they would drive sustainable economic growth, though the act of overcoming the regulatory hurdles is bound to be guided and characterized by responsive and adaptive management approaches.

Sustainability Evaluation: If the current trend in human capital and innovation development investments is maintained, Kosovo might very well sustain its economic growth and innovation, similar in nature to the long-term development trends that Murray et al. (2017) have discussed.

Artefact 2: Smart Mobility

Relevance Check: If all the planned intelligent transportation systems and green infrastructure projects are actually implemented in Kosovo, this could bring efficiency in urban transport and gains in environmental sustainability similar to those noted by Neirotti et al. (2014).

Effectiveness Evaluation: Provided that it manages to reduce traffic congestion and increase public transport efficiency, these efforts might easily enhance urban mobility, falling on similar lines looked at with success on traffic management by Saleem et al. (2022).

Efficiency Appraisal: With consideration of further investment in smart traffic management systems, the operational cost reductions could reflect efficiency gains like those induced within the Peja Smart City Initiative 2022.

Implementation Effectiveness Appraisal: That–in the event of maintained high quality of implementation of dynamic traffic systems and enhancement of public transportation networks–this would present the robust and efficient urban management systems brought about by Rittenbruch et al. (2021).

Impact Assessment: Should these smart mobility interventions realize their objectives, reduced urban congestion and pollution would entail high co-benefits environmentally and socially. Potential barriers could emanate from opposition by traditional transport sectors to the adoption of smart mobility.

Sustainability Appraisal: Should intelligent transportation systems make a case for scalability in 2023, as estimated by the OECD iLibrary, it will sustain the reduction in long-term urban congestion and alleviate environmental quality.

Artefact 3: Smart Governance

Relevance Evaluation: If the e-governance and open data initiatives had been expected to further proliferate in Kosovo, then it would have been significantly effective in bringing transparency and raising the efficiency of the government, in harmony with the modern digital governance trends as described by the World Bank, 2019.

Effectiveness Assessment: If digital portals and AI-driven tools had been improving access to and efficiency of public services, then over time, the streamlined government services could have been the reflection of improvements done in the realm of digital governance, as referred to by Vattapparamban et al. 2016.

Efficiency Evaluation: If the trend in automating administrative processes continues, cost decrements and better service delivery might be indicative of the administrative efficiencies pointed at by USAID, 2022.

Implementation Evaluation: Assuming development and implementation are robust for secure digital identification systems, it will help ensure integrity and security for digital transactions, echoing secure frameworks discussed by the World Bank, 2020.

Impact Evaluation: If this priority in enhanced transparency and efficient services should be stepped up, then they will most probably foster better public confidence. At the same time, the associated data standardization and interoperability challenges will most likely remain to be dealt with, requiring continued attention.

Sustainability Evaluation: If improvements in digital services and comparative transparency of government find continuity, then they might go on enabling sustainable effectiveness and good governance, as captured in the sustainable governance trends by the World Bank, 2023.

Artefact 4 - Smart People

Efficiency Evaluation: If continuous improvements in educational technology are undertaken, then the teaching methodologies and learning output may reach efficiencies as seen in the modern-day educational systems discussed by Peffers et al. 2007, resulting in highly skilled labor.

Implementation Evaluation: obe effectively implemented, digital education initiatives could really strengthen theBased on successful models of digital literacy and lifelong learning put forward by Carretero, Vuorikari, and Punie, 2017, these are groundwork for increasing entry and improving the quality of education in Kosovo.

Impact Evaluation: If digital inclusion and state-of-the-art educational initiatives were to continue in their growth, the resultant empowerment of citizens could be huge, eventually leading to increased societal equity and economic opportunity. However, that would require creativity and even more relentless efforts, especially in the rural areas.

Sustainability Evaluation: If investments in educational infrastructure and digital skills training are maintained, they could support enduring educational improvements and adaptability in the workforce, which aligns with UNDP Kosovo (2022) on sustainable education trends.

Artefact 5: Smart Living

Efficiency Evaluation: If the priorities remain in reducing the impact of eco-friendly construction technologies and smart home technologies, then these reductions in energy use, combined with resource management, could make for efficiency gains quite similar to those documented by the World Bank in 2023, after all for sustainable urban living.

Evaluation of the Implementation: Only if such advanced construction materials and AI technologies are integrated effectively will people live a better standard of living with safety at a higher level, just as in the articulated strategies for effective implementation by Rama in 2023.

Impact Evaluation: In case smart living solutions become very pervasive, enhancement to quality of life could be drastic—including safer, more sustainable living. However, the privacy concerns associated with AI and IoT in the residential setting will surely be an area calling for careful management to retain public trust.

Value Sustainability: If resiliently infrastructure-minded attention prevails, urban sustainability long-term gains could actually help sustain more long-term effects the UNDP Kosovo has pointed to in 2022, essentially setting a precedent for upcoming smart city developments.

Artefact 6 - Smart Governance

Sensitivity analysis: Assuming sustained acceleration of the automation of government processes and the implementation of digital services to this end, the administrative cost savings and improved service delivery might be significant enough to reflect efficiencies previously seen by USAID and to achieve improved public sector productivity gains.

Implementation Evaluation: If the development and implementation of secure digital identities and e-government portals are done properly, then strong and secure digital governance can be ascertained in adherence to the secure frameworks described by the World Bank, 2020.

If efficiency and transparency of government services continue to increase, then trust from citizens may also increase. However, some of the salient challenges discussed by the United Nations Development Programme, 2019, relate to data standardization and interoperability, which would demand constant attention and improvement.

Sustainability Evaluation: If improved e-services and openness of government are sustained, these can help entrench lasting efficiency and good governance—perhaps the index sustainability trends that the World Bank has monitored.

Within the evaluation phase, two major interviews were conducted. These interviews added more information regarding both the guidelines and the positives and negatives that could come by implementing them in Kosovo. Below, only answers that have one of the preset evaluation indicators will be shown.

Interview Date: 12.10.2023 – E.S - Business Owner

Relevance:

Q: How do you think the smart economy initiatives will benefit your business?

A: "The smart economy initiatives will provide better digital infrastructure, which is essential for expanding our online presence and improving operational efficiency."

Q: Do you believe the proposed improvements in digital infrastructure will meet your business needs?

A: "Yes, improved broadband connectivity and digital tools will greatly benefit our business operations, allowing us to reach more customers and streamline processes."

Effectiveness:

Q: What are your expectations regarding the impact of innovation hubs and technology parks on your business?

A: "I expect these hubs and parks to create a supportive ecosystem for startups and SMEs, offering networking opportunities, access to funding, and collaborative spaces."

Q: How do you think access to grants and tax incentives will influence your business growth?

A: "Access to grants and tax incentives will reduce our financial burden and allow us to invest more in research, development, and expansion."

Implementation:

Q: How important do you think collaborations with tech industries and government bodies will be for your business?

A: "Collaborations are vital. They can provide the necessary support, resources, and expertise to help businesses integrate new technologies and stay competitive."

Impact:

Q: What specific benefits do you hope to gain from the smart city initiatives?

A: "We hope to gain enhanced operational efficiency, better market reach, and increased opportunities for innovation and collaboration."

Q: Are there any challenges or unintended consequences you are concerned about?

A: "We are honestly concerned about potential data security issues."

Interview Date: 12.10.2023 – N.P – Junior Consultant on Infrastructure and Sustainability at Civitta

Q: With your focus on sustainable urban transport, how do you evaluate the implementation of Intelligent Transportation Systems (ITS) and electric vehicle (EV) infrastructure in Kosovo's current projects?

A: "The integration of ITS and EV infrastructure is a critical step for Kosovo. These technologies are essential for reducing urban congestion and minimizing environmental impact. However, the main challenges include securing funding and public acceptance. The opportunity here is to create a seamless mobility experience that can significantly enhance urban living."

Q: Considering artefacts that emphasize sustainability goals, like green infrastructure and pollution control, what key strategies would you recommend for municipalities to enhance their environmental impact?

A: "Municipalities should focus on scalable green infrastructure projects, such as expanding urban green spaces and implementing city-wide recycling programs. These initiatives should be data-driven, utilizing smart sensors and IoT to monitor environmental changes and pollution levels. The strategy is not just about technology but also about fostering community involvement and awareness."

Q: Smart living components prioritize eco-friendly construction and enhanced safety. How do these priorities align with your consultancy projects, and what impact do they have on sustainable urban development?

A: "These components are perfectly aligned with our sustainability objectives. Eco-friendly construction reduces the carbon footprint of new developments and enhances the resilience of urban areas. By integrating smart technologies, such as AI for energy management and safety systems, we can also improve the quality of life. The impact extends beyond environmental benefits to social and economic advancements."

As part of the empirical evidence supporting the implementation of smart governance within Kosovo's smart city framework, significant progress was observed following a series of interviews conducted for this thesis. Mayor Përparim Rama of Pristina provided a crucial update on the practical application of smart governance technologies in the capital city.

On his official Facebook page, Mayor Rama announced the finalization of an agreement with the Kosovo Police to install and maintain a network of surveillance cameras across public spaces in Pristina. This initiative highlights the proactive steps being taken towards enhancing urban security and integrating advanced technological solutions into public administration.

Quote from Mayor Përparim Rama (2023): "We have been in close cooperation with the Kosovo Police for the drafting of the agreement for the installation of the smart camera system and how to maintain the camera network in the capital's public spaces, an agreement which was signed today. Together with the Kosovo Police, we pledged to coordinate joint activities to improve security in the capital's public spaces."

This announcement is particularly relevant to this thesis as it illustrates a direct application of smart governance principles—specifically in the domain of public safety and surveillance, which are integral components of the smart city framework discussed. The implementation of such technologies is pivotal for the thesis' argument that effective smart city initiatives must include collaboration between various governmental bodies and the integration of cutting-edge technologies to enhance civic engagement and security (CUS-UBT, 2022; Dameri, 2017; Hajrizi, Balaj, & Rizani, 2023).

7. DISCUSSIONS

The 2022 case of NGO Block by Block is an example of this more nuanced approach to urban development is the concept by which co-modernization is led by its citizens. In this case, Minecraft was applied to allow a participatory redevelopment process of a market neighbourhood in low-income Pristina, which has for long been affected by intercommunity tensions owing to the legacy of civil war. The main goal was to engage a broad set of stakeholders: professionals, shopkeepers, and citizens from various communities in the redesign of their place to reinforce local democracy and inter-ethnic cohesion. A bottom-up approach seemed to be effective against the top-down procedures of urban planning. Smart city projects are also sensitive to the involvement of concerned citizens for the merging technologies and data-driven solutions to improve infrastructure and services. All cities are leaning towards transforming the effectiveness and connectedness in all spheres of step change with regard to efficiency and sustainability through technologies. However, it is well understood that such success is not only dependent on progress in technologies but also on including citizens meaningfully in the phases of planning and execution alike. In short, this is comodernization for it places human beings at the leading edge in deciding the shape of sustainable and socially connected urban space. Active engagement of citizens in smart city projects can make them more practical and more effective in meeting community needs and preferences; additionally, it can develop a sense of ownership and responsibility toward long-term success and sustentation of these initiatives. In Pristina, regeneration of public spaces had to be undertaken while taking care of complex social dimensions, encouraging sociological cohabitation. Block by Block is the participatory approach reminding us just how imperative it is to have inclusive urban planning techniques that take social cohesion as a first step. This approach gives a sense of greater ownership and collective responsibility and has been able to bridge social divides, in addition to covering infrastructural needs, as persons' decisions are directly integrated into the process. This case study, therefore, illustrates how participatory urban planning might fit into and add value to smart city initiatives. Smart cities are thus seen as one big technological fix destined for the solution of urban challenges, while the embedding of the participatory dimensions of comodernization would ensure the socially inclusive and culturally sensitive nature of those solutions. The Pristina example of Block by Block illustrated that incorporating technological innovation with rigorous community engagement generally would create more integral and effective strategies for urban development. In other words, smart cities and co-modernization approaches underline the unalienable role of people in the process of urban development. The urban environment created with the utilization of advanced technologies in smart cities but without active involvement of citizens cannot be sustainable, effective, and socially coherent. This participatory approach has been experienced by Pristina, and it makes a very valuable model for smart city initiatives in Kosovo, enhancing the social dimension.

7.1. Other Smart City Frameworks to consider

In a developing country's context, many proven theories of smart cities have shown high effectiveness. The Leapfrog Theory of Development posits that these countries can skip interim technologies and adopt those of the highest caliber, such as Kenya's M-Pesa, which involves millions of unbanked citizens in mobile banking (Mbiti & Weil, 2011). Frugal innovation theory emphasizes localized cost-effective innovations, exemplified by innovations like low-cost solar-powered lanterns in India for rural

electrification (Bhatti & Ventresca, 2013). Governance theory implies, for instance, context-specific governance. It is one that entails governance models that are contextual, such as in the case of Porto Alegre, Brazil, where its citizens were engaged in budget decisions due to new innovative mechanisms for participatory budgeting (Wampler, 2007). ICT4D theory utilizes information and communication technologies to design economic and/or social policies for the advancement of development goals. For example, e-governance efforts in Estonia have made government services quite efficient (Heeks, 2008). Social innovation theory considers community-oriented means such as in the case of Dhaka, Bangladesh, where sanitation efforts are undertaken to enhance hygiene in the informal settlements (Moulaert, MacCallum & Hillier, 2013). The Sustainable Livelihoods Approach concentrates on increased livelihoods in a sustainable manner and is exhibited in the agroforestry projects initiated in Kenya, raising the food security status as well as that of the incomes of farmers . Finally, the Public-Private Partnership Theory involves the public and private sectors together in a partnership to finance and execute projects, such as the infrastructure projects for the Delhi Metro in India . The Human Smart City Theory emphasizes the role of expertise in generating skills and creativity to develop city initiatives. Conversely, The Resilient Smart City Theory centers on the building of cities that resists shocks, as well as pressures. In addition, Data Informed City Governance Theory enables the process of decision making through analytics of data (Kitchin, 2014) ; whereas Collaborative Governance Theory would lay stress on value based collaboration by the stakeholders (Ansell & Gash 2008). Place Making theory is a reflection of creation of spaces (Wyckoff, 2014), and Smart Suburbanism theory is that of extending smart city principles into suburban areas (Burd, 2016). At its core, the Circular Economy Theory integrates resource efficiency practices. These theories reiterate how the technology innovation and partnerships can effectively be harnessed so as to help in dealing with some of the challenges cropping up to the developing nations.

8. CONCLUSION

In Kosovo, the creation of a smart economy offers both progress and challenges. Most of the important steps ahead were taken in the bigger towns; in rural areas, digital infrastructure and access to new innovative business models are not yet well provided for. A number of promising signs of development are revealed in the context of the startup ecosystem, which is still constrained by inappropriate regulations and a lack of funding opportunities. Education and training activities already exist and just require more inclusiveness and better financing. In the energy sector, smart grid projects are either planned or ongoing, but high costs and technical barriers are likely to stand in the way. This will call for further investment, updated regulations, and a special focus on bridging the urban-rural divide. Results show that Prishtina often exceeds air quality standards for PM2.5, particularly during the winter months, posing substantial health risks to its residents. This seasonal spike in air pollution is closely linked to increased heating demands, mostly based on coal and other solid fuels, with high PM and other pollutant emissions. Moreover, the rapid urbanization of Prishtina, along with a substantial rise in vehicle registration, has further added to the levels of pollution. The huge influx of vehicles, most of them outdated and not fitted with modern controls that reduce emissions, contributes immensely to deteriorating air quality. Heavy traffic not only contributes to high levels of particulate matter but also adds other dangerous pollutants into the air, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and volatile organic compounds. (MESP, Ministry of Environment and Spatial Planning, 2018) Another meaningful share of emissions comes from city power plants, mainly coal ones, contributing large amounts of sulfur dioxide, nitrogen oxides, and particulate matter. In addition, the prevailing use of coal for residential heating presents another problem, as individual households increase the general level of pollution. Among these factors, a hazardous situation for urban health and the urgent measures to keep under control and reduce air-pollution levels in Prishtina are shown.

Smart city governance is a mixture of public administration, private sector, and citizen participation; it deals not only with technology but with strategic governance and information management. It is the approach beyond the simple technological applications, one that encompasses social norms and information resources aimed at improving urban management and decision-making. The smart city governance approach gives birth to new stakeholder dynamics in which active participation and coordination becomes an important precondition for effective governance.

For developing countries, where every penny counts in this matter, finding out which dimensions of smart governance have more impact on its execution would probably mean a lot, so local governments can set some priorities when developing a smart city. Prishtina is not yet recognized as one of the smart cities over the globe, in spite of its high [internet] penetration rate and very stable ICT sector. The cities face problems in making proper use of innovation and technology and bringing about citizen participation through digital governance. Therefore, it is very important to identify, from such rapidly urbanizing settings, the crucial predictors of smart governance in order to address research gaps and assist city policymakers in encouraging smart development.

Building on some of the scant holistic works related to smart cities in Kosova, this project makes use of the results from a detailed survey in the construction of a unique framework integrating machine learning. The results from the survey, where a number of shortcomings were noted with regard to governance and infrastructure in Prishtina, form a basis for this attempt. The proposed framework

addresses these deficiencies by applying machine learning techniques to enhance the decision-making process, resource management, and public service delivery. It seeks to incorporate the aspect of sustainability by aligning itself with some of the important SDGs concerning sustainable cities and communities, industry innovation and infrastructure, and climate action. This approach will ensure that smart city governance advancements are not only operationally efficient but also send positive signals with respect to environmental sustainability and resilience. The framework aims to make Prishtina one of the leading examples within the developing context of urban sustainable development, hereby with technological solutions targeting the challenges and unique opportunities of the locale through the application of machine learning applications based on recent survey insights. Hence, the sub-components should strongly be taken into consideration by the importance projected by the policymakers elaborating cooperation, transparency, and data accessibility in city management practices.

In addition, improving infrastructure and public services should also be an intrinsic part of smart governance frameworks. These strategic priorities are not only going to improve governance outcomes for Prishtina but also offer a scalable model for other developing regions characterized by similar socio-economic contexts and financial constraints. Finally, it concludes with an appeal for more research into which mechanisms smart city management and collaboration can influence governance, and possible challenges experienced in developing countries.

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