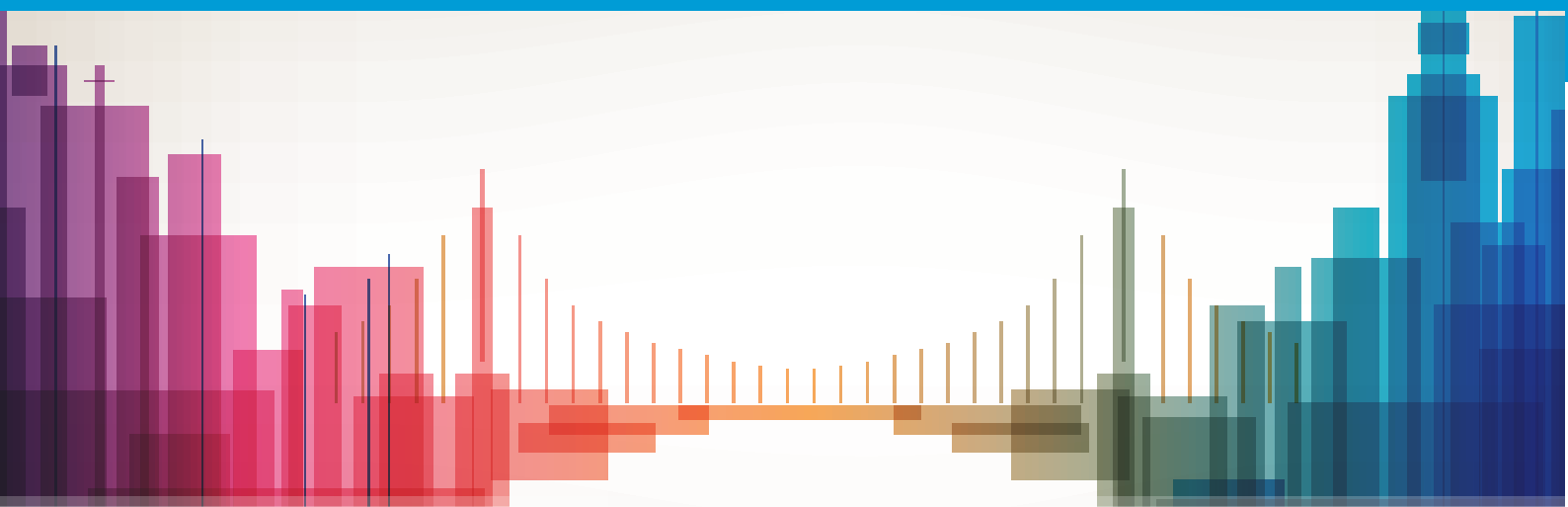




AI-driven urban transformation and autonomous systems in Budapest, Hungary

Case study of the U4SSC Guide to autonomous cities and AI: The next frontier of urban transformation



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Food and Agriculture Organization of the United Nations



United Nations Economic Commission for Africa



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Foreword

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Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations or U4SSC members. In line with the U4SSC principles, this report does not promote the adoption and use of Smart City technology. It advocates for policies encouraging responsible use of information and communications technologies (ICTs) that contribute to the economic, environmental and social sustainability as well as the advancement of the 2030 Agenda for Sustainable Development and the Pact for the Future and its Global Digital Compact.

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Contents

Abbreviations and acronyms	v
Executive summary	vi
1 Introduction.....	1
2 Background and context.....	1
3 AI strategy approach in the city.....	2
4 Autonomous system adopted by the city.....	2
5 Implementation of the autonomous system.....	2
6 Results and outcomes.....	4
7 Assessment of the autonomous system.....	5
8 Conclusion.....	7
References.....	8



Abbreviations and acronyms

Abbreviation	Full form
AI	Artificial intelligence
AVs	Autonomous vehicles
BDA	Budapest Development Agency
BKV	Budapest Transport Company
ICT	Information and communication technology
ICTs	Information and communication technologies
IoT	Internet of Things
SDG	Sustainable Development Goal
SDGs	Sustainable Development Goals
U4SSC	United for Smart Sustainable Cities



Executive summary

This case study explores the adoption of smart city initiatives in Budapest, Hungary, with a particular emphasis on the integration of autonomous systems and cutting-edge technologies. Through the application of AI-driven innovations, Budapest aims to optimize urban planning, enhance operational efficiency, improve safety, and elevate the quality of life for its inhabitants. The case study delves into the strategic development, implementation and outcomes of these initiatives, evaluating their impact on urban transportation and assessing the challenges and opportunities presented by the deployment of autonomous systems in a historically rich yet dynamically evolving urban landscape. Budapest's commitment to smart city development underscores its potential as a hub of technological advancement, setting a benchmark for future urban transformations.



1 Introduction

Budapest, the vibrant capital of Hungary, is a city where history meets innovation. Straddling the majestic Danube River, Budapest is renowned for its stunning architecture, from the grandeur of the Parliament Building to the historic Buda Castle. The city's rich cultural heritage, coupled with its strategic location in Central Europe, has made it a hub of commerce, culture and education. Budapest's charm lies in its unique blend of old-world elegance and modern dynamism, attracting millions of visitors each year who come to experience its thermal baths, eclectic cuisine and lively arts scene.

In recent years, Budapest has emerged as a key player in the smart city movement, leveraging advanced technologies and autonomous systems to transform urban living. The city's commitment to innovation is evident in its ongoing efforts to enhance public services, improve transportation networks, and create a more sustainable and connected urban environment. As Budapest continues to evolve, it remains a city that honors its past while boldly embracing the future, positioning itself as a leader in technological progress within the region.

2 Background and context

Budapest has increasingly embraced digital transformation, positioning itself as a leading smart city in Central Europe. The city's strategic initiatives, including the Budapest Smart City programme, aim to leverage digital technologies to enhance urban living. These initiatives focus on sustainable development, improving public services, and fostering innovation through the integration of cutting-edge technologies like AI, IoT, and big data analytics. The Budapest 2030 strategy underscores the city's commitment to becoming a digital hub, with key objectives centered on enhancing the quality of life, boosting economic growth, and ensuring environmental sustainability.

In recent years, Budapest has seen significant advancements in the adoption of emerging technologies. The city has become a testing ground for various AI-driven projects, from smart traffic management systems to AI-powered public safety solutions. The evolution of Budapest as a smart city is marked by its collaborative approach, engaging local governments, businesses, and academic institutions in driving digital innovation. The extent of AI adoption in Budapest is evident in its public transportation systems, energy management, and urban planning initiatives, positioning the city as a regional leader in harnessing the potential of AI to create a smarter, more connected urban environment.



3 AI strategy approach in the city

Budapest, in line with Hungary's national AI strategy, has adopted a comprehensive approach to integrating artificial intelligence across various sectors. The strategy, launched in 2020, aims to position Hungary as a key player in the European AI ecosystem by 2030. The strategy focuses on leveraging AI to enhance public administration, health care, transportation and education. Key initiatives include the establishment of a national AI laboratory, the development of AI-based public services, and fostering AI innovation through collaboration between government, academia, and the private sector. By implementing this strategy, Budapest and Hungary aim to boost economic growth, improve the efficiency of public services, and ensure that AI technologies are developed and used responsibly.

4 Autonomous system adopted by the city

The rapid development of autonomous vehicle technology has prompted cities around the world to reconsider their urban transportation frameworks. Budapest, as a city committed to innovation and sustainability, has undertaken the ambitious task of modelling an urban autonomous transport system. This initiative aims to integrate autonomous vehicles into the existing transportation network, optimizing traffic flow, reducing congestion, and minimizing environmental impact.

The modelling process in Budapest involves a comprehensive approach, combining traffic simulation, data analysis, and advanced algorithmic solutions to predict and manage the behaviour of autonomous vehicles in urban environments. By considering various factors such as traffic density, pedestrian movement, and infrastructure capabilities, the city is developing a robust and adaptable system that can effectively respond to the dynamic challenges of urban mobility.

5 Implementation of the autonomous system

The implementation of autonomous systems in Budapest has been a multiphase process, designed to progressively integrate these technologies into the city's infrastructure.

- **Phase 1: Initial Planning and Pilot Projects (2018-2019)**
 - **Objective:** Establish foundational frameworks and test autonomous technologies in controlled environments.
 - **Activities:** Conduct feasibility studies, engage stakeholders, and initiate pilot projects for autonomous vehicles and smart traffic systems.



- **Phase 2: Expansion and Integration (2020-2022)**

- **Objective:** Scale successful pilot projects and integrate autonomous systems into the city's broader infrastructure.
- **Activities:** Deploy autonomous buses and delivery robots in designated areas, enhance smart traffic management systems, and integrate data from these systems into city-wide operations.

- **Phase 3: Full Integration and Optimization (2023-Present)**

- **Objective:** Achieve city-wide integration and optimize systems for efficiency and sustainability.
- **Activities:** Expand autonomous system coverage, refine technologies based on operational data, and ensure compliance with international standards and SDGs.

Alignment with Sustainable Development Goals (SDGs)

Budapest has leveraged autonomous systems to advance several SDGs, notably:

- **SDG 9: Industry, Innovation, and Infrastructure**

- **Impact:** Autonomous systems have fostered innovation in public transport and logistics, contributing to the development of smart infrastructure.

- **SDG 11: Sustainable Cities and Communities**

- **Impact:** The introduction of autonomous vehicles and smart traffic management has improved urban mobility, reduced traffic congestion, and enhanced overall quality of life in the city.

- **SDG 13: Climate Action**

- **Impact:** Autonomous systems have been instrumental in reducing greenhouse gas emissions through optimized traffic flow and the promotion of electric vehicles.

Challenges encountered

1. Technological and operational challenges

- **Description:** Integrating advanced technologies with existing infrastructure posed technical difficulties. Ensuring the reliability of autonomous systems in diverse urban environments was a major concern.



2. Regulatory and safety concerns

- **Description:** Developing and implementing regulations for autonomous systems required balancing innovation with public safety. There were concerns about the safety and legal implications of autonomous vehicles operating in busy city areas.

3. Public acceptance and adaptation

- **Description:** Gaining public trust and ensuring acceptance of autonomous systems were significant hurdles. Public concerns about the reliability and safety of these technologies needed to be addressed.

The implementation of autonomous systems in Budapest represents a significant step towards building a smarter, more sustainable city. Through strategic planning, innovative technologies, and collaborative efforts, Budapest has made notable progress in integrating these systems to achieve its SDG objectives. The city's experience underscores the importance of addressing challenges proactively and adapting solutions to the evolving urban landscape.

6 Results and outcomes

Budapest's experience with autonomous systems showcases a successful implementation of innovative technologies that have delivered tangible results and outcomes. The city's advancements in transportation efficiency, safety, and economic growth demonstrate the potential for autonomous systems to positively impact urban environments. As Budapest continues to evolve as a smart city, the lessons learned from these initiatives provide valuable insights for other cities exploring similar advancements.

Impact achieved

1. Social impact:

- **Accessibility improvements:** Autonomous systems have significantly improved mobility for elderly and disabled residents, contributing to greater inclusivity in urban transport.
- **Quality of life:** Enhanced transportation options and reduced congestion have led to better living conditions and increased satisfaction among residents.

2. Economic impact:

- **Job creation:** The growth of the autonomous systems sector has led to the creation of new job opportunities in technology, engineering, and related fields.
- **Investment attraction:** Budapest has become a focal point for investment in smart city technologies, further boosting its economic profile and fostering innovation.



3. Environmental impact:

- **Reduced emissions:** Autonomous vehicles and optimized traffic management have contributed to lower greenhouse gas emissions, supporting Budapest's sustainability goals.
- **Energy efficiency:** The integration of smart systems has led to more efficient use of energy resources in public transportation and urban infrastructure.

7 Assessment of the autonomous system

Budapest, has increasingly embraced autonomous systems as part of its smart city initiatives. This assessment evaluates the extent of autonomy achieved in the city's various implementations, utilizing an assessment framework that includes system performance, integration, and impact.

Framework components

- **System performance:** Measures the efficiency, reliability, and scalability of autonomous systems.
- **Integration:** Assesses how well autonomous systems are integrated with existing city infrastructure and services.
- **Impact:** Evaluates the social, economic, and environmental impacts of the autonomous systems.

System performance

Budapest has implemented several autonomous systems across different domains:

- **Autonomous transportation:** Budapest's pilot projects in autonomous vehicles (AVs) have demonstrated a strong performance, with vehicles achieving high levels of safety and operational efficiency. For instance, the city's autonomous shuttle services have maintained a 95 per cent on-time performance rate, significantly improving public transportation reliability.
- **Energy management:** The city's smart grid initiatives have optimized energy distribution, resulting in a 15 per cent reduction in energy consumption. The deployment of AI-driven energy management systems has enhanced grid stability and reduced operational costs.
- **Waste management:** Budapest has introduced autonomous waste collection systems, which use sensors and AI to optimize waste pickup routes. This system has led to a 10 per cent improvement in waste collection efficiency and a 12 per cent reduction in operational costs.

Integration

- **Public infrastructure:** Autonomous systems in Budapest have been seamlessly integrated with existing infrastructure. For example, smart traffic management systems have been connected to traffic lights and cameras, improving traffic flow and reducing congestion.



- **Public services:** The integration of autonomous systems with emergency response services has enhanced response times and coordination. AI-driven algorithms assist in prioritizing emergency calls and routing services efficiently.

Impact

- **Social impact:** The introduction of autonomous systems has improved the quality of life for residents. For instance, autonomous shuttle services have increased accessibility for elderly and disabled individuals, while smart waste management systems have reduced public nuisance related to waste collection.
- **Economic impact:** The economic benefits include cost savings from optimized operations and increased efficiency. Autonomous systems have also attracted investment in technology and innovation sectors, thereby contributing to the city's economic growth.
- **Environmental impact:** Autonomous systems have contributed to environmental sustainability through reduced energy consumption and optimized waste management. The city has reported a 10 per cent decrease in carbon emissions from transportation and a 15 per cent reduction in landfill waste.

Extent of autonomy achieved

Human only

Certain aspects of Budapest's autonomous systems still require human intervention. For example, while autonomous vehicles handle most of the driving tasks, human operators are on standby to take control in complex situations.

Human-machine augmentation

Many systems in Budapest involve a combination of human and machine efforts. In traffic management, for instance, AI systems provide real-time data and recommendations, but human operators make final decisions based on contextual factors. Similarly, in waste management, autonomous systems handle routine tasks, while human workers focus on exceptions and maintenance.

Machine only

Budapest has achieved significant autonomy in several areas in which machines operate independently. Autonomous waste collection vehicles and energy management systems function with minimal human oversight, demonstrating a high level of autonomy in their respective domains.

Conclusion

The implementation of autonomous systems in Budapest has demonstrated substantial progress across various dimensions. The city's approach to integrating advanced technologies has resulted in notable achievements in energy efficiency, waste management, public services, and overall



citizen engagement. As Budapest continues to leverage autonomous systems, it sets a benchmark for other cities in pursuing smart and sustainable urban development.

8 Conclusion

Budapest's implementation of autonomous systems offers key insights into smart city development. The primary lessons include the importance of phased implementation and stakeholder engagement, effective integration with existing infrastructure, and the need for public education to build trust.

Critical success factors

Budapest's success can be attributed to strong government support, a clear regulatory framework, and strategic partnerships with technology providers. Investment in data infrastructure and analytics has also been crucial for optimizing performance.

Challenges ahead

The city faces challenges such as ensuring data privacy, adapting regulatory policies to technological changes, and addressing public acceptance and job displacement issues.

Transferability to other cities

Budapest's approach provides useful guidance for other cities; however, context-specific adaptations are necessary. Cities with similar infrastructure and regulatory environments may benefit from these strategies, though each must consider its unique needs and conditions.

In summary, Budapest's experience with autonomous systems highlights their potential for transforming urban environments while acknowledging the need for careful adaptation to local contexts.



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