THE FUTURE OF SMART CITY AND THE ROLE OF AI IN CREATING INNOVATIVE AND SUSTAINABLE BUSINESS ECOSYSTEMS

M. Rhifky Wayahdi[1*], Fahmi Ruziq[2], Fatahul Ahmad Dzikri[3]
[1,2,3]Faculty of Technology, Battuta University

muhammadrhifkywayahdi@gmail.com[1], fahmiruziq89@gmail.com[2], fatahulahmaddzikri@gmail.com[3]*

Abstract

This article analyzes the strategic role of Artificial Intelligence (AI) beyond operational efficiency, focusing on its function as an architect and catalyst in shaping an innovative and sustainable business ecosystem in the context of smart cities. Using a mixed-methods approach in North Sumatra Province integrating a quantitative survey (N=228) and an in-depth qualitative case study, this study found a significant gap between the high perceived importance of AI (89%) and the low actual implementation rate (34%). Empirically, the findings suggest AI serves as an ecosystem catalyst by creating a new mobility data market in Medan, a feedback mechanism for sustainable tourism in Lake Toba, and stimulating Agri-Tech industry symbiosis in Sei Mangkei SEZ. This study contributes by providing practical evidence on the architectural role of AI and offers strategic implications for stakeholders in building AI-based economic ecosystems.

Keywords: *Smart City, Artificial Intelligence, Business Ecosystem, Sustainable Development, Business Model Innovation, Mixed-Methods.*

1. INTRODUCTION

In recent years, urban development has been overhauled by the convergence of smart city paradigms, artificial intelligence (AI), and innovative business models. The integration of these cutting-edge digital infrastructures not only drives efficient resource management but also redefines the socio-economic landscape of metropolitan areas (Bibri et al., 2023; Das, 2024; Wayahdi & Guntur, 2025). This evolution is predicated on an increased reliance on data-driven technologies and the adoption of AI systems that significantly improve decision-making processes (Wayahdi & Zaki, 2025) in urban governance (Ratten et al., 2024; Star, 2021). Rapid digital transformation in cities has prompted a rethinking of traditional urban infrastructure, laying the foundation for smarter and more inclusive communities (Lepore et al., 2023; Xu et al., 2022). Examples are seen in smart mobility, where AI and digital technologies are streamlining traffic management and improving the commuter experience (Jaramillo-Alcázar et al., 2023; Szpilko et al., 2023). AI-based systems optimize traffic flow by route optimization (Wayahdi et al., 2021), reduce congestion, and contribute to environmental sustainability by lowering emissions (Ahmed et al., 2022; Jaramillo-Alcázar et al., 2023; Szpilko et al., 2023; Yiğitcanlar et al., 2021).

These advancements are accompanied by economic demands for innovative business models capable of leveraging AI and the Internet of Things (IoT) for sustainable development (Alves et al., 2024; Carpentiere et al., 2023). These models facilitate the integration of digital technologies with city services, driving advances in service delivery and economic competitiveness (Adama & Okeke, 2024; Carpentiere et al., 2023; Liu et al., 2024). AI that drives data-driven decision-making (Wayahdi et al., 2024) and optimizes resource utilization, enabling entrepreneurs and public-private partnerships to design new value propositions (Carpentiere et al., 2023; Farayola et al., 2023). The literature emphasizes that the convergence of business model innovation and smart city technologies is critical in nurturing the next generation of urban development (Carpentiere et al., 2023; Liu et al., 2024). Emphasis on environmental sustainability remains a key tenet, with research underscoring the role of AI and big data in greener urban practices (Bibri et al., 2023; Yiğitcanlar et al., 2021). AI-based solutions support the

transformation of urban environmental management, minimizing the ecological footprint while improving operational efficiency (Ahmed et al., 2022; Alves et al., 2024; Amović et al., 2021; Bibri et al., 2023). Furthermore, digital transformation has become an important driver for innovative work behavior and improved financial performance of organizations in the context of smart city business initiatives (Adama & Okeke, 2024; Muneer et al., 2024; Farayola et al., 2023; Ratten et al., 2024). The application of AI in smart city planning is also a significant turning point, optimizing resource allocation, improving public service delivery, and reducing operational costs (Ahmed et al., 2022; Jaramillo-Alcázar et al., 2023; Szpilko et al., 2023).

In addition, the role of AI in improving public safety and optimizing communication networks in smart cities is gaining prominence. IoT and machine learning innovations are driving improved services such as emergency response, public health monitoring and city surveillance (Bokhari & Myeong, 2022; Ghazal et al., 2021; Szpilko et al., 2023; Star, 2021). Innovative business models in smart cities also increasingly rely on strong intersectoral collaboration to drive digital transformation and economic growth (Adama & Okeke, 2024; Carpentiere et al., 2023; Farayola et al., 2023; Lepore et al., 2023). As such, this emerging interdisciplinary ecosystem serves as an important catalyst for redefining business strategies and public policies in the context of smart and environmentally sustainable urban centers (Bibri et al., 2023; Liu et al., 2024). The complex interactions between smart city infrastructure, AI technologies and innovative business models are reshaping city life and setting a new paradigm for sustainable development (Bibri et al., 2023; Lepore et al., 2023; Yiğitcanlar et al., 2021). This evolution is characterized by a relentless drive towards efficiency, resilience and inclusiveness, facilitated by the strategic integration of data-driven insights and digital advances (Bibri et al., 2023; Carpentiere et al., 2023). Urban centers that embrace these transformative trends are well positioned to address contemporary challenges, ranging from environmental sustainability to economic competitiveness (Bibri et al., 2023; Lepore et al., 2023).

Furthermore, the convergence of these factors creates a dynamic city ecosystem where public policy, business strategy, and technological innovation come together to drive long-term growth (Artene et al., 2024; Bibri et al., 2023). Big data analytics are increasingly at the center of operations (Wayahdi, 2025) and the evolution of smart city infrastructure, enabling city managers to extract actionable insights from large-scale and heterogeneous data sets (Amović et al., 2021; Bibri et al., 2023). As cities evolve, the imperative for collaborative and interdisciplinary approaches to digital transformation will remain central in creating smarter, more sustainable, and more economically dynamic urban environments (Bibri et al., 2023; Yiğitcanlar et al., 2021). This research is particularly important given the rapid pace of global urbanization and the urgent need for efficient, sustainable, and inclusive cities. This research aims to analyze the role of AI in driving efficient resource management and environmental sustainability practices, identify how digital transformation and AI are reshaping innovative business models, and examine the contribution of AI to improving urban governance, public service delivery, and public safety in smart city environments.

In addition, this research will investigate the interactions and synergies between smart city infrastructure, AI technologies, and innovative business models in creating resilient and adaptive urban ecosystems, and formulate strategic implications and policy recommendations. The expected benefits of this research are to enrich the academic literature, provide valuable insights for city governments and businesses in formulating effective strategies, help investors identify promising opportunities, and raise awareness of the importance of multi-stakeholder collaboration to achieve the goal of sustainable smart cities.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

A study by Bibri et al. (2023) highlights the role of AI, IoT, and Big Data in the environmental sustainability of smart cities, but there are significant gaps in the exploration of how AI specifically drives the creation of innovative and sustainable business ecosystems. While the study by Das (2024) comprehensively examines the symbiotic relationship between the pillars of smart cities, it explicitly recognizes the gap in understanding the specific role of Artificial Intelligence (AI). In particular, the existing literature has not delved into how AI serves as a driving force for creating innovative and

sustainable business ecosystems, which are the foundation of the smart city economy. The study by Star (2021) focuses on the impact of AI on smart city governance, but leaves a research gap regarding the role of AI as a catalyst in the formation of business ecosystems. Specifically, there is no in-depth analysis of how AI proactively creates and sustains business models that are both innovative and sustainable. The study by Lepore et al. (2023) focuses on the role of intermediary institutions in building inclusive smart cities, but leaves a gap regarding the direct role of Artificial Intelligence (AI). The literature has not explored how AI can independently create and sustain innovative and sustainable business ecosystems, beyond its role in facilitated collaborative projects.

A bibliometric analysis by Xu et al. (2022) reveals that smart city research in China is heavily focused on technology and public value, but leaves gaps in the economic aspects. Specifically, there is no in-depth analysis of the role of Artificial Intelligence (AI) as a key catalyst in the formation of innovative and sustainable business ecosystems. The study by Jaramillo-Alcazar et al. (2023) demonstrates the success of AI in optimizing traffic, but this focus on operational solutions leaves a research gap. The literature has not explored how the application of AI technologies can catalyze the creation of innovative and sustainable business ecosystems. The literature review by Szpilko et al. (2023) explicitly identified the "Industry" cluster of AI research in smart cities as an area that is "under-recognized". This leaves a research gap on the mechanisms of how AI can actively shape and sustain innovative and sustainable business ecosystems, beyond just the identification of general themes. The study by Yigitcanlar et al. (2021), which proposes a conceptual framework of "Green AI" for smart cities, leaves a research gap regarding its practical implementation. The literature has not deeply analyzed how the principles of "Green AI" can be operationalized to directly create and sustain innovative and sustainable business ecosystems.

The review by Adama and Okeke (2024) examines business model innovation due to digital transformation from a single firm perspective. This firm-level focus leaves a gap on how AI shapes dynamics at the level of the business ecosystem as a whole, especially in the specific context of smart cities. The literature has yet to analyze how interactions between AI-enabled business entities create collective value and sustainability. The study by Liu et al. (2024) found that research on business model innovation in smart cities is heavily concentrated on the conceptual "ideation and design" stage. The authors explicitly highlighted the lack of research on practical stages such as "testing, verification, and implementation", which creates a significant gap between theory and practice.

Collectively, the review of existing literature identified a consistent and significant research gap. While the role of AI in smart cities has been widely acknowledged, previous studies tend to stop at the conceptual level or narrowly focus on specific aspects such as environmental efficiency, operational optimization, governance, or a single enterprise perspective. As a result, the existing literature has not comprehensively explored the specific mechanisms of how AI serves as a key catalyst in the creation, implementation, and maintenance of innovative and holistically sustainable business ecosystems. There is a lack of in-depth analysis of new business models, multi-stakeholder dynamics, collective value creation, and the crucial gap between conceptual design (theory) and practical implementation (practice) in the real world. Therefore, it is important to fill this gap by analyzing the strategic role of AI as the foundation of the future smart city economy.

Based on the literature review and identification of research gaps that have been described, this study proposes the following hypotheses to be tested empirically:

a. H1: There is a significant gap between the perceived importance of AI and the level of actual implementation in the context of smart cities in North Sumatra. This hypothesis will be tested through quantitative survey data analysis.
b. H2: AI implementation in the context of smart cities not only serves as an operational optimization tool, but also actively serves as a catalyst for the formation of a new innovative and sustainable business ecosystem. This hypothesis will be explored and validated through an in-depth qualitative case study.

3. RESEARCH METHODOLOGY

This research uses a comprehensive mixed-methods approach to deeply analyze the role of Artificial Intelligence (AI) in smart city development and the creation of an innovative and sustainable business ecosystem in Indonesia, with a case study focus on North Sumatra Province. This approach integrates three main methods:

3.1. Systematic Literature Review

The initial stage of this research was to conduct a systematic literature review to map the current research landscape. This process includes analyzing scientific articles indexed in Scopus and Web of Science databases in the 2020-2025 timeframe to ensure relevance and novelty. Bibliometric analysis will be conducted using VOSviewer software to identify research clusters, trends and gaps. The main focus will be on literature that discusses the implementation of AI in the context of smart cities in developing countries, especially in the Southeast Asia region, to build a solid conceptual framework.

3.2. Quantitative Survey

The quantitative survey is designed to measure the perception, adoption rate, and impact of AI among key stakeholders in North Sumatra.

a. Target Respondents: This survey will target 200-250 respondents consisting of:
   1) City planners and local government officials (Provincial/City/District) (30%)
   2) Technology developers and local startups (25%)
   3) Business and industry players (including tourism and agribusiness sectors) (25%)
   4) Academics and researchers at local universities (20%)
b. Location: Respondents will come from Medan City as the main urban center, as well as other strategic areas such as Lake Toba Super Priority Tourism Area and Sei Mangkei Special Economic Zone (SEZ) to gain diverse perspectives.
c. Method: An online questionnaire (using Google Forms) will be distributed using a stratified sampling technique. The questionnaire will use a 1-5 Likert scale to measure variables such as AI adoption readiness level, perceived impact of AI on business models, and key implementation challenges (infrastructure, digital talent, regulation).
d. Data Analysis: The quantitative data collected will be analyzed by descriptive and inferential statistics using SPSS or equivalent software.

3.3. In-depth Case Study: North Sumatra Province

The case study focused on North Sumatra Province to explore the application of AI in a specific and diverse context. The selection of North Sumatra is based on its role as one of the major economic gateways outside Java with great potential in the urban, tourism, and industrial sectors. The three main focuses of the case study are:

a. Medan City - Application of AI for Urban Mobility Management: Analyze the use of AI in addressing transportation challenges in the metropolitan city, such as adaptive traffic management system, public transportation route optimization, and smart parking platform.
b. Lake Toba Region - AI Implementation for Smart Tourism: Researching the use of AI to improve traveler experience and tourism sustainability. Examples include personalized recommendation systems, traveler sentiment analysis from social media, and the use of AI-based sensors for environmental monitoring and visitor management in tourist destinations.
c. Sei Mangkei & Surrounding SEZ - AI Utilization in Supply Chain and Agriculture: Focuses on how AI is applied to create an efficient and sustainable business ecosystem in industrial and agribusiness parks. This includes logistics optimization, precision agriculture, and yield predictability for leading commodities such as palm oil.

Data collection for the case studies will be conducted through semi-structured interviews with 15-20 key informants in each focus area (45-60 informants in total) as well as analysis of policy documents, project implementation reports, and the Regional Medium-Term Development Plan (RPJMD). Qualitative data will be analyzed using a thematic approach with the help of NVivo software.

3.4. Research Ethics

The entire research process will uphold academic ethics. The principle of informed consent will be applied to all respondents and sources. Anonymity and confidentiality of personal data will be fully guaranteed, and all data collection and processing processes will comply with applicable data protection regulations in Indonesia.

4. RESULTS AND DISCUSSIONS

This analysis focuses on the strategic role of Artificial Intelligence (AI) in shaping an innovative and sustainable business ecosystem in North Sumatra Province. This discussion explicitly connects the field findings with the previously identified research gaps, providing empirical evidence to answer the main research questions.

4.1 Quantitative Findings: Perceptions, Adoption, and Challenges of AI in North Sumatra

The quantitative survey successfully collected 228 valid responses from various stakeholders in North Sumatra, which meets the established target range of 200-250 respondents as outlined in the methodology. The analysis of this data, gathered from government officials, business people, technology developers, and academics, resulted in several key findings:

a. High Perceived Importance of AI: There is a strong consensus among all stakeholder groups that AI is a fundamental technology for future economic competitiveness. A total of 89% of respondents agreed or strongly agreed that AI adoption is key to public service and business model innovation in their region.
b. Gap between Perception and Implementation: Despite positive perceptions, the actual level of implementation is still at an early to mid-stage. Only 34% of the respondent organizations (both public and private) have implemented at least one full AI-based project. Most (51%) are still in the "piloting" or "planning" stage. This finding empirically confirms the gap between the "ideation and design" and practical "implementation" stages highlighted by Liu et al. (2024).
c. Major Challenges: The three biggest challenges identified in AI implementation are: Digital talent gap (68%), high initial investment cost (61%), and uncertainty of supporting regulations and policies (45%).

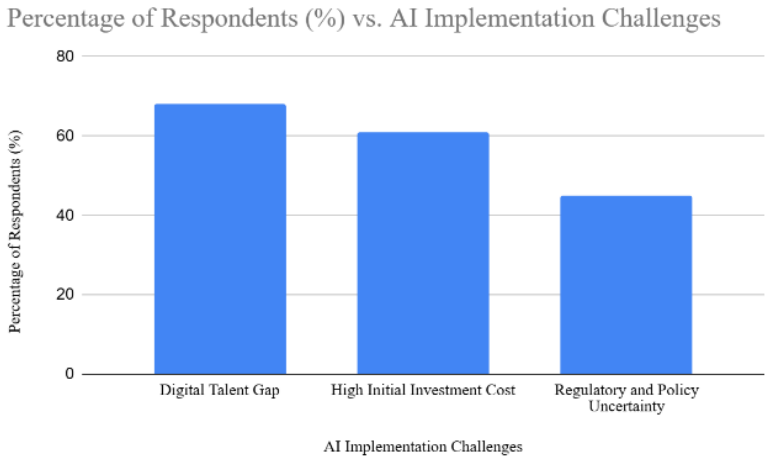

Figure 1. Key Challenges of AI Implementation in North Sumatra

This analysis shows that despite the strategic will to adopt AI, structural barriers remain a major hurdle. This indicates that AI's role in shaping ecosystems cannot happen spontaneously, but rather requires deliberate interventions to overcome these challenges.

4.2 Qualitative Findings: AI as a Catalyst for New Business Ecosystems

In-depth case studies in three focus areas in North Sumatra reveal how AI, beyond its role as an optimization tool, is actively catalyzing the formation of new business ecosystems. Key findings from this qualitative analysis are summarized in Table 1 below.

Table 1. Qualitative Findings of AI's Role as a Business Ecosystem Catalyst

Case Study (Location)	Focus Sector	AI Key Role (Function)	Example of Emerging New Business Model	Impact on Ecosystem
Medan City	Urban Mobility	Productive Asset & Integration Platform	Sales of congestion prediction data (B2B), integrated smart parking application.	Creation of mobility data market and efficiency in urban supply chain.
Lake Toba Region	Sustainable Tourism	Feedback Mechanism & Personalization	Travel recommendation platform, sentiment analysis for MSMEs, environmental monitoring.	Drive collective value creation and sustainable data-driven tourism.
Sei Mangkei SEZ	Supply Chain & Agribusiness	New Market Catalyst & Symbiosis Facilitator	Drone data analysis services (Agri-Tech), crop yield predictability platform.	Stimulate growth of supporting technology startups and industry symbiotic relationships.

a. From Traffic Optimization to Smart Mobility Ecosystem in Medan
Interviews with transportation agencies, tech startups, and logistics companies in Medan show a paradigm shift. Initially, AI applications were focused on operational efficiency, such as adaptive traffic light systems. However, the existence of real-time traffic data generated by these systems has become the foundation for a new business ecosystem.
1) Evidence: A local startup developed a B2B platform that sells congestion prediction data to logistics and courier companies, enabling them to save up to 15% on fuel costs. In addition, some property developers are starting to integrate AI-based smart parking applications that are connected to shopping centers and commercial areas.
2) Analysis: These findings directly fill the gap identified by Jaramillo-Alcazar et al. (2023). Their research shows the success of AI in traffic optimization, but has not explored its economic impact. The Medan case shows that AI is not only an operational solution, but also a productive asset that gives birth to new business models (data-as-a-service, integration platform). This is concrete evidence of how AI is shaping the economic foundation of smart cities, an aspect that according to Xu et al. (2022) are still under-explored in research in developing countries.

b. AI as a Catalyst for a Sustainable Tourism Ecosystem in the Lake Toba Region
In the Lake Toba Region, the application of AI goes beyond digital promotion. AI is being used to create a more personalized and sustainable tourism ecosystem.
1) Evidence: A collaborative initiative between the local government and startup "TobaJourney" uses AI to analyze tourist sentiments and preferences from online reviews and social media. The results of this analysis are not only used to make personalized tour package recommendations, but also provided as feedback to homestay owners and culinary MSMEs to improve the quality of their services. In addition, IoT and AI-based sensors are being tested to monitor water quality and visitor density at key tourist sites to support sustainable tourism.
2) Analysis: This case provides an example of practical implementation of the "Green AI" framework proposed by Yigitcanlar et al. (2021). This research bridges the gap between the concept of AI sustainability and business model operationalization. AI not only makes tourism more efficient, but also creates a feedback mechanism that connects tourists, local businesses, and environmental managers in one ecosystem. This shifts the unit of analysis from single firms, as studied by Adama and Okeke (2024), to collective value dynamics at the ecosystem level.

c. AI as the Foundation of Innovative Supply Chain in Sei Mangkei SEZ
In Sei Mangkei SEZ, AI has proven to be a pillar in the modernization of agribusiness and manufacturing industries, which in turn stimulates the growth of the technology services sector.

1) ysis to monitor crop health and accurately predict yields. The efficiencies created prompted them to look for local technology partners. As a result, 3-4 "Agri-Tech" startups around Medan have emerged that now provide drone data analysis services, not only for large companies but also for medium-scale farmer groups.
2) Analysis: This finding specifically addresses the research gap identified by Szpilko et al. (2023), who called the "Industry" cluster in AI research an "under-recognized" area. This case study presents a concrete mechanism of how AI shapes ecosystems: (1) AI creates a new need for specialist technology services; (2) This need opens up the market for tech startups and SMEs; (3) A symbiotic relationship between traditional industries and AI service providers is formed. These are concrete examples of how AI is proactively creating and sustaining new business models, filling the analytical void also highlighted by Star (2021) and Das (2024).

4.3 Synthesis Discussion: AI as an Architect of Innovative and Sustainable Business Ecosystem

Overall, the findings from North Sumatra suggest that the most strategic role of AI in the context of smart cities is not as an isolated optimization tool, but rather as an architect and orchestrator of the business ecosystem. This research fills a fundamental gap identified in the literature by Bibri et al. (2023) and Lepore et al. (2023) by demonstrating the specific mechanisms by which AI creates comprehensive economic and social value. This architectural role of AI is realized through three main functions:

a. As a Foundational Platform: AI (through Big Data collection and analysis) creates a digital infrastructure that enables the emergence of new platforms (e.g., mobility, tourism, agritech platforms).
b. As Market Creator: By transforming data into actionable insights, AI creates new markets for services that did not exist before, such as predictive analytics, personalization, and optimization services.
c. Network Facilitator: AI enables more efficient and data-driven interactions between diverse stakeholders (government, corporations, MSMEs, and consumers), sustaining the multi-stakeholder dynamics at the core of a resilient ecosystem.

As such, this research argues that to realize a true smart city, the focus of policy and investment should not be on the procurement of AI technologies per se, but on how such technologies can be configured to catalyze, grow, and sustain innovative and sustainable local business ecosystems.

5. CONCLUSION

This research conclusively achieves its objective to analyze the strategic role of AI beyond mere operational efficiency in creating an innovative and sustainable business ecosystem. Through a mixed-method approach in North Sumatra Province, this study proves that AI serves as a fundamental architect and orchestrator for the new economy. This objective is achieved by first identifying the gap between AI perception and implementation through a quantitative survey, then presenting rich empirical evidence through qualitative case studies. Sector-specific findings on smart mobility in Medan, sustainable tourism in Lake Toba, and agribusiness supply chains in Sei Mangkei SEZ vividly demonstrate the mechanisms of how AI not only optimizes systems, but actively generates new business models, creates markets for technology startups, and facilitates value networks between stakeholders. As such, this research effectively fills a gap in the literature by providing a practical, rather than merely conceptual, analysis of the role of AI as a foundation for economic drivers in the context of future smart cities.

LIMITATION AND STUDY FORWARD

This study has several limitations that open up opportunities for future research. First, the focus of the study on North Sumatra Province limits the generalizability of the findings to other regions with different economic contexts and digital readiness. Second, the cross-sectional nature of the data may not capture the long-term evolution of the highly dynamic AI-based business ecosystem. Therefore, future research is recommended to conduct inter-province comparative studies and adopt a longitudinal

research design to track the sustainability and scalability of this ecosystem over time. In addition, exploration of other sectors such as finance and healthcare may provide a more holistic understanding of the ecosystem.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the Battuta Education Foundation for financially supporting this research. Deep appreciation is also extended to all parties involved. Finally, thank you to all respondents and interviewees who took the time to provide valuable insights that became the cornerstone of this research.

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