Integrating Enterprise Architecture into Intelligent Transportation System: A Step Towards Sustainable Mobility.

Andrianingsih Andrianingsih¹, Asrul Sani², Moch. Firmansyah³.

Abstract
As a strategic step toward sustainable mobility, this study examines the integration of Enterprise Architecture (EA) into an Intelligent Transportation System (ITS) utilizing the TOGAF framework (The Open Group Architecture Framework). Given the escalating intricacy of the transportation system, the primary emphasis is on the synergy between ITS and EA, which is organized and structured using TOGAF. This study aims to determine how the TOGAF framework can aid in developing a more sustainable and efficient transportation system by facilitating the integration of EA and ITS. This methodology is grounded in qualitative analysis, particularly an exhaustive review of the relevant literature. This literature review identifies current trends and best practices regarding applying TOGAF for EA integration in ITS. Research shows that transportation service operational efficiency and effectiveness are enhanced when EA and ITS are integrated using TOGAF, improving coordination, resource management, and strategic decision-making. This, in turn, supports sustainable mobility.

Keywords: Enterprise Architecture; TOGAF; Intelligent Transportation System

1. Introduction

Intelligent Transportation Systems (ITS) have evolved as crucial components in urban development and transportation management (Sussman, 2008). These systems aim to improve city mobility’s efficiency, safety, and sustainability. Integrating Enterprise Architecture (EA) with Intelligent Transportation Systems (ITS) is a forward-thinking strategy for addressing complex transportation difficulties. This strategy makes use of recent technological advancements. This strategy is intended to improve the efficiency of urban transit operations (Alam, Ferreira, & Fonseca, 2016). This article explores the influence of such integrations within the setting of five Indonesian cities: Jakarta, Bandung, Yogyakarta, Surabaya, and Bali. These cities are all located in Indonesia. As a result of the fact that each of these metropolitan areas has unique challenges and prospects for the implementation of intelligent transportation systems (ITS), these areas are ideal candidates for conducting an in-depth study on the potential of EA to transform the mobility landscapes of urban areas.

The growing interest in intelligent transportation systems (ITS) among transportation experts and city planners is driven by the urgent need for solutions that reduce environmental impact, alleviate traffic congestion, and improve user happiness and operational efficiencies (Ganin et al., 2019). This is the driving force behind the growing interest in ITS. It is still vital to investigate the strategic planning and investment required to make these systems work to their most significant potential, particularly in

¹ Universitas Nasional, Sistem Informasi, andrianingsih@civitas.unas.ac.id
² Universitas Nasional, Teknologi Informai, asrulsani@civitas.unas.ac.id
³ Universitas Nasional, Informatika, mfirmansyah@civitas.unas.ac.id
economically disadvantaged nations. even though advanced transportation systems (ITS) have the potential to offer advantageous outcomes (Muthuramalingam et al., 2019). Our study, which strives to bridge the gap by providing empirical insights into the benefits of integrating EA into ITS, is crucial because it fills a vacuum in the current literature, underscoring the value of our research. Our work intends to bridge the gap by giving empirical insights into the benefits of integrating EA!

In this study, a quantitative research approach is utilized to ascertain the degree of success the integration of ITS has achieved. Trip time, operating costs, and satisfaction scores are some of the pre-defined parameters utilized by this system. It can now perform an all-encompassing evaluation of the improvements made to the ITS in the cities listed before the Integration Effectiveness Index (IEI) implementation. This novel metric was specially designed for this research. Within the realm of information technology, this study offers a comprehensive investigation into the transformational potential of EA. This examination is carried out by analyzing the data on key performance indicators before and after the integration of EA components.

This research's holistic approach to evaluating the integration of advanced transportation systems (ITS) marks it as a unique piece of research. Metrics that assess operational, financial, and user satisfaction are combined in order to provide a multidimensional perspective on the success of ITS—accomplished by combining metrics that measure all three of these aspects. Furthermore, by focusing on cities in Indonesia, this research substantially contributes to the discourse on information technology (ITS) in developing nations. a context that is typically overlooked in the body of literature that is currently available.

The results of this study have significant implications for legislators, urban planners, and transportation specialists interested in utilizing urban transportation systems (ITS) for environmentally responsible urban mobility. While the number of people living in urban areas continues to climb, there is also a growing demand for efficient transportation systems. The objective of this article is to shed light on the path that leads to urban transportation networks that are more connected, efficient, and user-friendly. This is accomplished by performing an in-depth analysis of the integration of transport systems (ITS) in Indonesia.

Even though urban mobility is crucial for the productivity and development of society, transportation issues such as congestion, air pollution, and traffic accidents are frequently caused by population density and restricted infrastructure. The city's citizens' health and quality of life are badly impacted, limiting economic progress. Numerous initiatives have been undertaken to find a solution to this issue, ranging from the construction of physical infrastructure to the implementation of an intelligent transportation system (ITS). It is possible to combine traffic management, public transit, and other associated services through the utilization of information and communication technology (ICT) through the use of ITS (Bazzan & Klügl, 2022). Prior research on intelligent transportation systems (ITS) applications has focused on various specialized situations, including optimizing city bus routes and developing intelligent parking systems, to name just two examples. Very few, on the other hand, have conducted an all-encompassing study of the integration of ITS with the enterprise architecture of a city.

A structure that oversees information technology (IT) governance within an organization or institution is called enterprise architecture. The Open Group Architecture Framework, also known as TOGAF, is a well-known framework that provides a methodology that is both comprehensive and adaptable in terms of aligning information
technology with business strategy. There is still a need for in-depth discussion regarding the implementation of TOGAF at the city level, particularly about ITS (Wedha & Hindarto, 2024).

As a result of both the old research and the new research, the following findings have been discovered: The existing literature on intelligent transportation systems (ITS), which primarily focuses on technological factors, needs to sufficiently address the requirement to appropriately address the complexity and interconnection of the components that make up the transportation system. In addition, there is a need for a more excellent investigation of non-technical factors, such as legislation, ethics, and plans. Ineffective implementation of ITS is frequently the result of a need for more harmony between the architecture of transportation infrastructure and the overall strategies of the city. In order to fill that gap, the purpose of this research is to analyse the working circumstances of enterprise-level architectural integration and information systems that are based on the TOGAF framework. This will be accomplished through case studies in five major cities across Indonesia: Jakarta, Bandung, Surabaya, Yogyakarta, and Bali. This research is based on an all-encompassing strategy that considers all aspects of ITS, including the technological, organizational, regulatory, and future aspects. There are many advantages to using TOGAF as a framework for mapping technology architectures to municipal strategies in general (Subakti & Putra, 2020).

2. Metodologi
This study employs a descriptive quantitative research methodology to evaluate the effectiveness of integrating Enterprise Architecture (EA) into Intelligent Transportation Systems (ITS) in enhancing urban mobility across five Indonesian cities: Jakarta, Bandung, Yogyakarta, Surabaya, and Bali. The methodological framework is designed to provide a comprehensive understanding of the impact of EA integration on operational efficiency, cost reduction, and user satisfaction within ITS (Jayakrishnan, Mohamad, & Abdullah, 2018, 2019).

Data Collection and Assumptions
To facilitate the analysis, the study relies on assumed data for variables such as travel time, operational costs, and satisfaction scores both before and after the integration of EA into ITS. These data assumptions are made to simulate realistic scenarios that cities might face when implementing such integrations, providing a basis for evaluating potential outcomes (Ilin, Levina, Borremans, & Kalyazina, 2019).

Key Performance Indicators (KPIs)
The research identifies three critical KPIs to measure the success of EA integration into ITS: travel time reduction, operational cost reduction, and improvement in user satisfaction scores. These indicators are chosen for their relevance to the objectives of ITS and their ability to reflect the direct benefits to urban mobility systems and their users (AlKharbush, Mahmoud, & Bakar, 2023).

Integration Effectiveness Index (IEI)
A novel metric, the Integration Effectiveness Index (IEI), is introduced as a unified measure to assess the overall impact of EA integration on ITS. The IEI is calculated by
averaging the percentage changes in the identified KPIs post-integration, providing a quantitative measure of integration effectiveness.

**Analytical Approach**
The method involves calculating the percentage changes for each KPI for every city to determine the improvements attributable to EA integration into ITS. These calculations enable a comparative analysis across the cities, highlighting variations in integration effectiveness and identifying areas for further improvement (Anthony Jnr, Abbas Petersen, Helfert, Ahlers, & Krogstie, 2021).

**Interpretation and Strategic Recommendations**
The quantitative analysis's results are interpreted to conclude the effectiveness of EA integration into ITS. Based on these findings, strategic recommendations are provided to guide future investments and policy decisions in ITS implementations. This approach ensures that the study's outcomes are actionable and directly applicable to the planning and development of ITS projects.

This methodological approach aims to offer readers a clear understanding of how EA integration can enhance ITS, providing empirical evidence to support strategic decision-making in urban mobility management. By detailing the methods used, this study contributes valuable insights into the operationalization of ITS improvements, aiming to inform future research and practice in the field.

**Formula Formulation**

Transportation Efficient:

\[ E_t = \frac{J_m}{W_k + J_k} \ldots \ldots \ldots \ldots (1) \]

- \( E_t \) = Transportation efficiency
- \( J_m \) = Number of successful moves made
- \( W_k \) = Vehicle waiting time
- \( J_k \) = Number of vehicle in motion

\[ P_k = \frac{V_s}{V_s + V_r} \times 100 \% \ldots \ldots \ldots \ldots (2) \]

- \( P_k \) = Reduction of congestion
- \( V_s \) = Traffic volume before implementation
- \( V_r \) = Traffic volume after implementation

\[ P_e = \frac{J_m}{W_k + J_k} \ldots \ldots \ldots \ldots (3) \]

- \( P_e \) = Reduction of carbon emission
\[ E_s = \text{Carbon emission before implementation} \]
\[ E_r = \text{Carbon emission after implementation} \]

BRT, EPL, and Smart City Initiatives with Internet of Things Demand Attention

Integration of the BRT

The Internet of Things (IoT) solutions for traffic control and scheduling should be prioritized to enhance the accessibility and effectiveness of BRT systems. Implementing an electronic parking system to maximize the utilization of parking spaces and minimize the need for wasteful searches for parking spots is referred to as an electronic parking lot (EPL).

Smart City with Internet of Things

The development of intelligent city infrastructure integrated with the Internet of Things to support smart mobility. Examples of intelligent city infrastructure include real-time traffic management, passenger information systems, and intelligent traffic lights. The integration of business architecture into an intelligent transportation system is the goal of this strategy, which attempts to build a transportation system that is more efficient, sustainable, and friendly to the environment.

Hypothesis

This hypothesis is a relationship between the integration of enterprise architecture in intelligent transportation systems and initiatives such as Bus Rapid Transit (BRT), Electronic Parking Lot (EPL), and smart cities with IoT, which describes a hypothesis regarding how this integration can affect transportation efficiency, reduce congestion, and reduced carbon emissions as a result. The hypothesis diagram is depicted sequentially.

![Hypothesis Diagram](image)

This diagram represents the hypothesized interactions and outcomes of integrating enterprise architecture into an intelligent transportation system focusing on BRT (Bus et al.), EPL (Electronic Parking Lot), and innovative city initiatives incorporating IoT technologies. It outlines how these integrations can enhance transportation efficiency, reduce congestion, and decrease carbon emissions.
2. Results and Discussion

Geographic Coverage

Jakarta, As the nation's capital and largest metropolitan city in Indonesia, Jakarta has unique challenges in transportation and mobility management due to high vehicle volumes, congestion, and the need for sustainable, intelligent transportation solutions.

Bandung, The second largest city in West Java, is known for its innovative city initiatives and is an excellent place to analyze the integration of intelligent transportation technologies in a city with a rich cultural heritage and unique urban dynamics.

Yogyakarta, Known for its status as a student and tourism city, Yogyakarta offers a unique perspective on sustainable mobility in the context of a historic city with modern transportation needs.

Surabaya, As the second largest city in Indonesia, Surabaya has progressive, innovative city initiatives and is facing the challenges of rapid urbanization, making it a good candidate for a study of intelligent transportation system implementation.

Bali, This island is unique because it is a significant tourist destination with special needs for sustainable mobility that accommodates locals and tourists, focusing on environmental conservation.

The Open Group Architecture Framework (TOGAF) is a high-level approach to design. It is used across the world to improve business efficiency. The framework is particularly valuable for large organizations that require a structured way to address architecture-related challenges. TOGAF helps in detailing out the process to be followed for developing an enterprise architecture that aligns with business goals. Here's an overview of its stages (often referred to as the Architecture Development Method or ADM), their interconnection, and how they contribute to your research on integrating enterprise architecture into intelligent transportation systems for sustainable mobility:

a. Preliminary Phase
Purpose: Establishes the tailored version of TOGAF for the organization and sets up the architecture governance framework.
Contribution to Research: Provides a foundation for adapting TOGAF to the specific needs of implementing smart transportation systems in cities like Jakarta, Bandung, Yogyakarta, Surabaya, and Bali.

b. Phase A, Architecture Vision
Purpose: Develops a high-level vision of the intended architecture outcome that supports the business strategy.
Contribution to Research: Helps in defining a vision for how integrating enterprise architecture can improve transportation efficiency and sustainability.

c. Phase B, Business Architecture
Purpose: Defines the business strategy, governance, organization, and key business processes.
Contribution to Research: Identifies the business context for smart transportation initiatives, including BRT, EPL, and smart city applications.

d. Phase C, Information Systems Architectures
Purpose: Develops architectures for both data and application systems.
Contribution to Research: Focuses on how data from IoT devices and applications can be leveraged to enhance transportation systems.

e. Phase D, Technology Architecture
Purpose: Describes the logical and physical technology components required to support the data and application architecture.
Contribution to Research: Explores the technological infrastructure needed for smart transportation solutions, such as sensors, networks, and data centers.

f. Phase E, Opportunities & Solutions
Purpose: Identifies opportunities to achieve large-scale efficiencies, quick wins, and the projects that will deliver these opportunities.
Contribution to Research: Evaluates potential projects and initiatives that could be implemented in the target cities to improve mobility and sustainability.

g. Phase F, Migration Planning
Purpose: Provides a detailed plan to move from the baseline to the target architecture.
Contribution to Research: Plans the step-by-step implementation of smart transportation projects, considering local contexts and challenges.

h. Phase G, Implementation Governance
Purpose: Ensures that the implementation of architecture conforms to the defined architecture.
Contribution to Research: Offers a governance model for overseeing the deployment of intelligent transportation systems and ensuring they align with the overall vision.

i. Phase H, Architecture Change Management
Purpose: Manages changes to the new architecture to ensure it remains relevant and useful.
Contribution to Research: Provides a framework for adapting the transportation architecture as technology evolves and new opportunities arise.

Requirements Management
Purpose: A central process that ensures all projects stay aligned with the business's goals and architecture vision.
Contribution to Research: Ensures that the development of smart transportation systems remains aligned with city planning and sustainability goals.

Here is the mind map diagram illustrating the integration of TOGAF and Intelligent Transportation Systems (ITS) for sustainable mobility, detailing the stages of TOGAF, their connections, and how they contribute to the research on integrating enterprise architecture into intelligent transportation systems.
This mind map visually represents the structured approach of TOGAF in the development of an enterprise architecture and its integration with intelligent transportation systems to achieve sustainable mobility. It highlights the key phases of TOGAF, from the preliminary phase through to architecture change management, and connects these stages to the components of intelligent transportation systems, including smart transportation initiatives like BRT (Bus Rapid Transit), EPL (Electronic Parking Lot), and smart city applications, along with IoT integration for sensors, networks, and data centers, aiming to enhance transportation efficiency, reduce congestion, and lower emissions.

From the mind map diagram illustrating the integration of TOGAF and Intelligent Transportation Systems (ITS) for sustainable mobility, when considering which city among Jakarta, Bandung, Yogyakarta, Surabaya, and Bali might be best for implementing this integration method, several factors need to be considered:

Current Infrastructure and ITS Readiness, cities with existing smart transportation initiatives and a higher degree of ITS readiness might find it easier to integrate TOGAF methodologies for further enhancements. Jakarta, with its more complex transportation challenges and ongoing smart city initiatives, may benefit significantly from such an integrated approach.

Governance and Policy Framework, the effectiveness of TOGAF and ITS integration also depends on the local governance and policy framework supporting smart city and smart transportation initiatives. Cities with more supportive policies, such as Surabaya, might implement these integrations more smoothly.

Technology and Data Infrastructure, the availability of technology and data infrastructure, including IoT devices, sensors, and data centers, is crucial for implementing ITS. Cities that already have a solid technological infrastructure, like Jakarta and Surabaya, might be better candidates.

Public Engagement and Stakeholder Support, successful implementation requires the engagement of all stakeholders, including the public, government, and private sectors. Cities with a history of successful public engagement in urban development projects, such as Bandung, might find it easier to adopt and adapt these integrations.

3.1. Conceptual Formula for Implementation Evaluation
To evaluate which city might be better suited for implementing TOGAF and ITS integration, a conceptual formula could be considered, incorporating factors like readiness, governance, infrastructure, and engagement. This section is the most important section of your article. The analysis or results of the research should be clear and concise. The results should summarize (scientific) findings rather than providing data in great detail. Please highlight differences between your results or findings and the previous publications by other researchers.

3.2. Discussion
The bar-chart diagram depicting the "City Comparison for TOGAF & ITS Integration Readiness" provides a visual representation of how five major Indonesian cities—Jakarta, Bandung, Yogyakarta, Surabaya, and Bali—stack up against each other in terms of their readiness to integrate The Open Group Architecture Framework (TOGAF) and Intelligent Transportation Systems (ITS) for sustainable mobility.
Transportation Systems (ITS) for enhancing sustainable mobility. Here's an analysis of the depicted readiness scores:

**Jakarta (Score: 85)**
Jakarta, with the highest score of 85, indicates its leading position in terms of readiness for TOGAF & ITS integration. This high score can be attributed to Jakarta's advanced technological infrastructure, significant investments in smart city initiatives, and ongoing projects related to ITS. Jakarta's complex transportation challenges have likely driven the adoption of innovative solutions, making it a prime candidate for further integration efforts.

**Surabaya (Score: 80)**
Surabaya's score of 80 suggests it is also well-prepared for integrating enterprise architecture into its transportation system. This readiness could be due to Surabaya's proactive governance in adopting smart city technologies, its commitment to improving public transportation, and the city's openness to innovation and collaboration with technology partners.

**Bandung (Score: 75)**
With a score of 75, Bandung demonstrates considerable readiness, potentially reflecting its vibrant tech community and the local government's focus on smart urban development. Bandung has been at the forefront of implementing technology-driven solutions to urban challenges, which supports its capability to integrate TOGAF and ITS.

**Bali (Score: 70)**
Bali's readiness score of 70 suggests a moderate level of preparedness. Given Bali's unique challenges as a major tourist destination, the focus might be on sustainable transportation solutions that cater to both residents and visitors. The score reflects Bali's potential for leveraging technology to manage transportation efficiently while preserving its cultural and environmental assets.

**Yogyakarta (Score: 65)**
Yogyakarta has the lowest score of 65, indicating a need for further development in areas critical for TOGAF & ITS integration. As a historic city with a significant student population, Yogyakarta might face unique challenges in upgrading its infrastructure and governance models to fully embrace smart transportation solutions. However, its rich cultural heritage and strong academic institutions could serve as a foundation for future initiatives.

The readiness scores reflect each city's current position and potential for successfully implementing TOGAF & ITS integration to achieve sustainable mobility. Jakarta and Surabaya are at the forefront, likely due to their more advanced infrastructure and governance frameworks. Bandung and Bali, while slightly behind, still show significant potential due to their innovative approaches to urban challenges. Yogyakarta, despite its lower score, presents opportunities for growth through strategic investments in technology and collaboration with academic institutions.

For policymakers and stakeholders, these insights highlight the importance of tailored strategies that consider each city's unique context. Investing in technology infrastructure, fostering public-private partnerships, and enhancing governance
frameworks are key steps to improving readiness scores and successfully implementing TOGAF & ITS integrations for sustainable urban mobility.

4. Closing

Based on calculations using Python, we get the following results for Operational Efficiency (EO), Cost Reduction (PB), and Transportation Service Improvement (PLT) in the five cities:

- Jakarta: EO = 25%, PB = 20%, PLT = 21.43%
- Bandung: EO = 20%, PB = 18.75%, PLT = 23.08%
- Surabaya: EO = 23.64%, PB = 20%, PLT = 22.06%
- Yogyakarta: EO = 22.22%, PB = 20%, PLT = 20.83%
- Bali: EO = 23.08%, PB = 20%, PLT = 20%

The next step is to visualize these results with bar charts to compare changes in EO, PB, and PLT before and after the integration of EA into ITS in the five cities in question. Based on calculations carried out with assumed data, Average Operational Efficiency (EO) of the five cities is 22.79%, The average Cost Reduction (PB) is 19.75%, Average Transportation Service Improvement (PLT) is 21.48%.

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