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Enterprise Architecture for Integrated Smart-Township Operations Using TOGAF ADM, ArchiMate, and Zachman Framework

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Abstract: Master-planned townships represent a predominant model of urban expansion in Indonesia, each governed by an operational entity that concurrently coordinates residents, commercial tenants, estate-management teams, and third-party service providers. However, the operational systems supporting these developments remain predominantly fragmented—characterized by estate dues tracked on disparate spreadsheets, resident inquiries and incident reports handled via informal messaging channels, and gate access logged manually—depriving township operators of an integrated, auditable, and data-rich operational platform. Objective: This study establishes a completeness-driven enterprise architecture (EA) framework for integrated smart-township operations. Method: Grounded in Design Science Research, the architecture was developed using the TOGAF Architecture Development Method across Phases A to D, modeled in ArchiMate 3 using the Archi modeling tool, and systematically validated through cross-layer consistency verification, an As-Is versus To-Be gap analysis, and a Zachman 5W1H completeness assessment. Results: The Architecture Vision establishes end-to-end alignment between five stakeholder groups, six strategic operational goals, and their requisite resources. Three core processes—estate dues billing, facility booking with smart access, and resident service with security incident response—are traced from business workflows through application services to underlying cloud and cyber-physical infrastructure, with shared services providing modular integration boundaries. Technology-layer specifications formalize external payment gateways and IoT network connections. The Zachman completeness evaluation indicates that 20 of the 24 cells achieve full coverage, while the remaining four cells (three partial and one weak) converge exclusively within the temporal (When) dimension. Conclusion: The developed enterprise architecture provides an extensible, auditable blueprint for operator-managed townships with an empirically documented coverage profile, wherein the identified temporal gaps establish an explicit empirical trajectory for operational lifecycle scheduling and governance extensions.

Keywords: Enterprise Architecture; TOGAF ADM; ArchiMate; Smart Township; Zachman Framework.

1. Introduction

A growing proportion of new urban development in Indonesia is organized as master-planned townships: sizeable, privately developed estates that integrate residential, commercial, and shared public amenities under the centralized governance of an estate operator. Unlike stand-alone residential towers or isolated commercial offices, a master-planned township requires large-scale, concurrent operational coordination across multiple stakeholder segments, which directly determines resident satisfaction and long-term asset value. As urban communities increasingly embrace technology-supported living, integrated digital services have emerged as the foundation of this coordination, with contemporary scholarship emphasizing enterprise-scale platforms rather than isolated point-solution mobile applications as the critical determinants of smart-community maturity (Bastidas *et al.*, 2022; Lloret *et al.*, 2025; Yamamoto, 2022). In daily operations, however, township governance frequently relies on disconnected, manual workflows. Recurring estate service dues are typically recorded in spreadsheets and paid via isolated bank transfers without centralized ledger reconciliation; inquiries, maintenance requests, and security incidents are processed through informal messaging channels that lack auditability; and facility reservations and perimeter gate access are managed manually at physical service counters. These operational fragmentation practices present substantial operational risks. Manual coordination bounds service quality to individual staff bandwidth, the lack of consolidated transactional records denies operators the operational data required for longitudinal planning, and siloed access control compromises both physical security and tenant satisfaction. Recent studies on facility and real-estate management corroborate this operational challenge, establishing direct links between manual, siloed workflows, degraded service performance, and poor support for evidence-based decision-making (Demirdöğen *et al.*, 2023; Ehab *et al.*, 2024; Pomè *et al.*, 2026). Consolidating these core functions into a single enterprise platform provides a decisive resolution to operational fragmentation. Through unified billing, access management, service ticket dispatch, and incident coordination, operators can replace ad-hoc handling with standardized, repeatable procedures, embed physical security into daily workflows, and establish an auditable central data repository. However, architecting such a unified ecosystem entails considerable structural complexity. A township operator must simultaneously address five major stakeholder groups—estate executive leadership, on-site estate management personnel, residents, commercial tenants, and external service partners for security, maintenance, and financial transactions. Furthermore, the operator must manage multiple parallel revenue and service channels—encompassing recurring maintenance charges, facility booking fees, and value-added services—while integrating cyber-physical Internet-of-Things (IoT) hardware, such as smart turnstiles, license-plate recognition barriers, and surveillance streams, into the overarching transactional IT landscape (Monios *et al.*, 2026; Park *et al.*, 2021; Sabit & Tun, 2024). This interplay of diverse stakeholders, multi-stream monetization, and cyber-physical infrastructure firmly positions township management within the scope of complex enterprise systems requiring disciplined architectural modeling.

Enterprise Architecture (EA) provides the requisite discipline to align business strategy, application services, and underlying infrastructure into a cohesive roadmap, with established literature confirming that mature EA practices are vital to digital transformation outcomes (Alghamdi, 2024; Dumitriu & Popescu, 2020; Lukáš *et al.*, 2025). Among established EA frameworks, the TOGAF standard and its Architecture Development Method (ADM) offer a widely adopted, iterative approach that anchors technology investments directly to overarching business goals (Kornyshova & Deneckère, 2022; The Open Group, 2022b). ArchiMate complements TOGAF by providing a formal, standardized modeling language across the business, application, and technology layers that facilitates clear communication between executive leadership and technical architects (The Open Group, 2022a; Zhi & Zhou, 2022), having been proven effective in depicting municipal-scale smart-city architectures (Yamamoto, 2022). Two primary gaps in the existing literature establish the motivation for this research. The first gap relates to the domain scope of architectural artifacts. Applied TOGAF and ArchiMate designs in prior literature are overwhelmingly concentrated on single corporate enterprises—such as property developers, commercial banking systems, hospital networks, and theme parks (Gunawan *et al.*, 2021; Purnama *et al.*, 2026; Sentosa *et al.*, 2024; Widjaja *et al.*, 2025)—or bounded within the internal IT departments of individual organizations (Izzati *et al.*, 2020). Conversely, enterprise architecture applied at broader spatial scales predominantly targets municipal-level, government-administered smart cities (Bastidas *et al.*, 2022; Prasetyo & Habibie, 2022). Systematic inquiries across Scopus, Google Scholar, and Garuda reveal an absence of published studies addressing mid-scale, operator-managed smart townships—developments characterized by multi-tenant operations, recurring service monetization, and cyber-physical access orchestration—as a unified enterprise architecture spanning TOGAF ADM and ArchiMate end to end. The second gap concerns validation methodology. Systematic literature reviews on EA evaluation highlight that prevailing applied TOGAF designs are validated almost exclusively through baseline gap analysis or descriptive qualitative walkthroughs (Khairina *et al.*, 2024), without formal verification of descriptive architectural completeness. In contrast, the Zachman Framework provides an established taxonomy for evaluating descriptive completeness across six foundational interrogatives: What, How, Where, Who, When, and Why

(Sowa & Zachman, 1992; Zachman, 1987). Prior theoretical studies indicate that the Zachman taxonomy and TOGAF process are fundamentally complementary, pairing taxonomic coverage rigor with process-driven transformation discipline (Iyamu, 2023; Reiter, 2025).

This study resolves both identified gaps by engineering a completeness-driven enterprise architecture for master-planned township operations that employs TOGAF ADM to drive lifecycle design, ArchiMate 3 to formalize cross-layer models, and the Zachman 5W1H interrogatives to systematically assess descriptive coverage. The resulting blueprint articulates an optimal To-Be target architecture for fragmented township environments. The investigation is guided by four primary research questions:

1) At the Architecture Vision stage (Phase A), what motivational architecture aligns township stakeholders, strategic objectives, and operational resources (RQ1)?
2) Across the business, application, and technology layers (Phases B through D), how should core township workflows—comprising estate dues billing, facility reservation with smart access, and resident service management with security response—be structurally integrated (RQ2)?
3) Which structural architectural gaps separate the fragmented As-Is baseline from the target To-Be design, and how are these deficiencies resolved (RQ3)?
4) When evaluated against the Zachman 5W1H interrogatives, what degree of descriptive completeness does the proposed architecture achieve, and which architectural viewpoints require subsequent elaboration (RQ4)?

The contributions of this study are threefold: establishing a reusable, multi-layer enterprise architecture blueprint for operator-run townships that explicitly models service monetization and cyber-physical IoT access; demonstrating an auditable evaluation method that operationalizes the Zachman 5W1H taxonomy as a coverage-verification mechanism over a TOGAF–ArchiMate artifact; and conducting a systematic completeness evaluation that verifies structural coverage while identifying temporal lifecycle dynamics as an empirical priority for future architectural evolution. The remainder of this article is structured as follows: Section 2 reviews related literature and positions the study; Section 3 details the Design Science Research methodology and validation instruments; Section 4 presents and discusses the architecture models across Phases A to D, the gap analysis, and the Zachman completeness findings; and Section 5 concludes the paper with implementation recommendations and future research directions.

2. Related Work

2.1 Enterprise Architecture and Its Foundational Frameworks

Over the past three decades, Enterprise Architecture (EA) has evolved from a passive documentation practice into a strategic instrument for directing digital transformation. Contemporary scholarship substantiates this evolution across multiple domains: disciplined EA adoption correlates significantly with transformation success across industries (Alghamdi, 2024), enterprise-wide architecture frameworks guide large-scale sector transformation programs (Lukáš *et al.*, 2025), and EA functions as an enduring governance mechanism aligning technology implementations with strategic business objectives (Dumitriu & Popescu, 2020). Two long-standing architectural paradigms frame contemporary practice: the Zachman Framework and The Open Group Architecture Framework (TOGAF). The Zachman Framework represents an analytical ontology rather than a procedural methodology (Sowa & Zachman, 1992; Zachman, 1987). Its matrix organizes six fundamental interrogatives—What, How, Where, Who, When, and Why—across multiple perspectives, establishing a taxonomy for evaluating architectural descriptive completeness, wherein populated cells confirm descriptive coverage and unaddressed cells highlight architectural blind spots (Iyamu, 2023). Conversely, TOGAF provides a process-centric standard centered on the Architecture Development Method (ADM), executing an iterative lifecycle spanning the Preliminary Phase, Architecture Vision (Phase A), Business Architecture (Phase B), Information Systems Architectures (Phase C), Technology Architecture (Phase D), and subsequent implementation governance (The Open Group, 2022b). This methodology supports contextual tailoring across specialized operational domains (Kornyshova & Deneckère, 2022) and provides structured guidance for greenfield enterprise systems design (Oberle *et al.*, 2023).

2.2 Modeling Language and the Completeness Gap

Contemporary enterprise architecture increasingly treats the Zachman Framework and TOGAF as complementary instruments, wherein Zachman ensures descriptive coverage and TOGAF provides process discipline (Iyamu, 2023; Reiter, 2025). The practical alignment between these frameworks relies on standardized modeling notations, with ArchiMate establishing the predominant standard for representing TOGAF ADM artifacts across the business, application, and technology layers (Zhi & Zhou, 2022). Recent applied studies corroborate the utility of pairing Zachman interrogatives with formal ArchiMate models to structure and evaluate architectural artifacts (Marnoto, 2025). However, while systematic literature reviews document diverse methodologies for evaluating enterprise architecture (Khairina *et al.*, 2024), prevailing applied TOGAF literature relies primarily on baseline gap analysis, qualitative walkthroughs, or single-technology performance benchmarking, without executing formal assessments of descriptive coverage. This methodological absence defines the procedural gap addressed in this study. This structural complementarity becomes critical when designing cyber-physical enterprise services. While TOGAF ADM dictates lifecycle phases, it does not specify an exhaustive matrix of descriptive perspectives. Conversely, the Zachman taxonomy remains agnostic toward lifecycle processes while demanding exhaustive structural description. In a smart-township environment where service delivery is split between transactional software engines and physical cyber-physical devices—such as automated turnstiles, credential readers, and surveillance hardware—this distinction prevents operational actors, physical hardware deployment nodes, and policy rules from remaining implicit assumptions rather than formally modeled entities. Research on access-control mechanisms and IoT platforms for collaborative environments indicates that spatial and organizational actors represent primary architectural concerns (Monios *et al.*, 2026; Park *et al.*, 2021), precisely reflecting the descriptive dimensions verified by the Where and Who perspectives within an architectural taxonomy.

2.3 Applied EA Case Studies and the Smart-Community Scale

Empirical enterprise architecture case studies are well established, spanning varied commercial and public domains: optimizing revenue cycles in real-estate enterprises (Widjaja *et al.*, 2025), defining operational capabilities for digital challenger banks (Sentosa *et al.*, 2024), mapping entertainment park workflows (Gunawan *et al.*, 2021), structuring digital advertising operations (Pratama, 2024), orchestrating municipal e-government services (Afarini & Hindarto, 2023), integrating clinical radiology systems (Purnama *et al.*, 2026), and formalizing retail supply chains (Hengky *et al.*, 2024) and maritime cruise operations (Watasendjaja *et al.*, 2025). Furthermore, Hamdani *et al.* (2026) demonstrated the integration of TOGAF with Design Science Research, establishing precedent for treating architectural blueprints as formalized research artifacts. Similarly, bounded enterprise scopes are addressed through targeted IT architecture designs for small-and-medium enterprises (Izzati *et al.*, 2020). A common characteristic of these studies is their focus on a single corporate boundary or a unidirectional service model. At the opposing macro scale, enterprise architecture is applied to municipal contexts: Bastidas *et al.* (2022) defined a foundational research agenda for smart-city enterprise architecture, Yamamoto (2022) evaluated smart-city reference architectures using ArchiMate, and Prasetyo and Habibie (2022) formulated a framework for developing municipal smart-city systems. However, this municipality-level governance tier differs substantially from the operational dynamics of an individual operator administering an integrated private community.

2.4 Positioning of This Study

The operator-managed master-planned township occupies a distinct intermediary scale between the single corporate enterprise and the municipal smart city: it combines multi-tenant community governance with commercial service monetization and cyber-physical infrastructure management. Although supporting technologies for this domain are advancing rapidly—including open IoT platforms for smart communities (Monios *et al.*, 2026), fail-safe smart building systems (Sabit & Tun, 2024), integrated Building Information Modeling (BIM) and IoT facility frameworks (Demirdöğen *et al.*, 2023; Ehab *et al.*, 2024), next-generation automated access architectures (Park *et al.*, 2021), and property-technology (PropTech) management tools (Pomè *et al.*, 2026)—these implementations focus on specialized point solutions without reconciling technology components with overarching business capabilities. Establishing this structural alignment represents the primary objective of Enterprise Architecture. Table 1 positions this study alongside relevant prior literature across domain scope and validation rigor.

Table 1. Comparative Analysis of Related Research

Study	Domain Object	Framework / Validation	Gap Addressed by This Study
Widjaja *et al.* (2025)	Revenue processes in one real-estate firm	TOGAF ADM + ArchiMate; gap analysis	Bounded to single enterprise; lacks operator-run community scope
Sentosa *et al.* (2024)	Digital-bank features	TOGAF ADM + ArchiMate; gap analysis	Single financial product domain; excludes physical community operations
Izzati *et al.* (2020)	Internal IT of one organization	TOGAF ADM; descriptive	Internal corporate IT; does not address multi-stakeholder operator ecosystem
Bastidas *et al.* (2022); Prasetyo & Habibie (2022)	Government-led smart city	EA research agenda / framework	Macro municipal scale; does not address single-operator commercial governance

Sabit & Tun (2024); Park *et al.* (2021)	Building management / access control	Technology design; performance	Point-solution engineering; lacks business–IT alignment and EA framework
This study	Operator-run master-planned township	TOGAF ADM + ArchiMate + Zachman 5W1H; consistency + gap + completeness	Integrates multi-stakeholder community operations, monetization, and IoT access with formal completeness verification

As highlighted in Table 1, existing literature bifurcates into either corporate-level enterprise architectures or macro-level smart-city initiatives, leaving operator-run townships unaddressed. Consequently, this study establishes an integrated architectural artifact that bridges this structural divide, validated through formal descriptive completeness to ensure robust business–IT alignment.

3. Methodology

3.1 Research Approach

This study is conducted within the Design Science Research (DSR) paradigm, a methodological framework dedicated to creating and evaluating innovative artifacts designed to solve identified organizational problems (Hevner & Chatterjee, 2010). The DSR paradigm is well suited to this investigation because the primary research contribution is an engineered enterprise architecture blueprint rather than an empirical measurement of an existing system. Furthermore, DSR provides a rigorous operational structure that bridges the contextual problem domain, the iterative artifact design cycle, and the foundational academic knowledge base. The problem domain encompasses Indonesian master-planned township operations and their primary stakeholder groups—including estate executive leadership, on-site management units, residents, commercial tenants, and external service partners—alongside the structural fragmentation that impedes coordinated governance. The foundational knowledge base integrates the TOGAF standard, the ArchiMate modeling language, the Zachman taxonomy, and established enterprise architecture literature. Because the resulting artifact addresses a generalized class of operational environments characterized by fragmented township administration rather than a single proprietary property, architectural requirements were synthesized through a generalized township Business Model Canvas, mirroring methodological precedents in TOGAF-based DSR literature (Hamdani *et al.*, 2026). The developed model represents an idealized To-Be target architecture for this class of developments.

3.2 Design and Validation Stages

The investigation was executed across five sequential stages, as illustrated in Figure 1. Stage 1 established the theoretical foundation through a systematic literature review that identified the empirical and methodological gaps in contemporary enterprise architecture research. Stage 2 synthesized organizational requirements using a township Business Model Canvas that delineates the operator's strategic vision, recurring and auxiliary revenue streams, key architectural resources, and external partner channels. Stage 3 executed the core architectural design using TOGAF ADM from the Preliminary Phase through Phase D, encompassing the Architecture Vision (Phase A), Business Architecture (Phase B), Information Systems Architectures (Phase C), and Technology Architecture (Phase D), with each domain deliverable formalized in ArchiMate 3.2 using the Archi modeling tool. Consistent with comparable enterprise architecture studies, the design scope was bounded at Phase D, as Phases A through D constitute the essential architecture-definition cycle, whereas subsequent phases govern operational procurement and organizational migration assuming an active deployment infrastructure (Purnama *et al.*, 2026; Widjaja *et al.*, 2025).

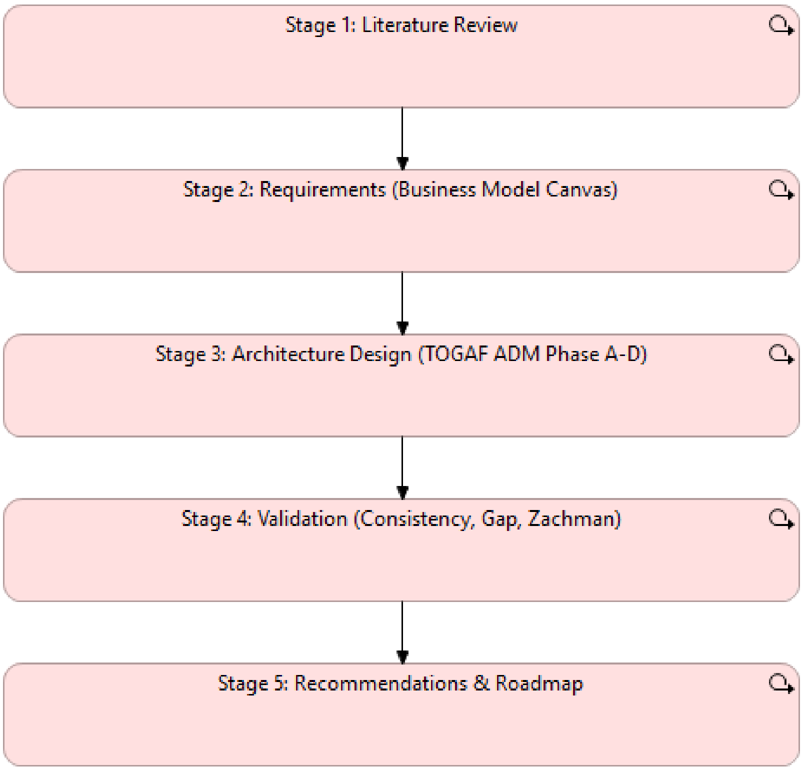

Figure 1. Research methodology: a five-stage Design Science Research process integrating TOGAF ADM, ArchiMate, and the Zachman completeness lens.

Stage 4 established the methodological evaluation of the artifact through three complementary validation instruments. The initial instrument performed automated cross-layer dependency tracing across the formalized Archi model, which encompasses 88 architectural elements and 113 structural relationships. Three mandatory syntactic relationship rules were enforced: 1) every business process must serve as the target of a Serving relationship originating from an application service; 2) every application service must maintain an Access relationship with at least one persistent data object; and 3) every application service must be realized through a Realization relationship originating from an underlying technological node or cyber-physical device. Architectural elements failing to satisfy these structural rules were flagged as dangling dependencies, ensuring verification remained mechanical and syntactically deterministic. All modeled relationships conformed strictly to the ArchiMate 3.2 specification derivation table. The secondary instrument executed a multi-layer gap analysis comparing the fragmented As-Is baseline directly against the target To-Be architecture, verifying that each baseline deficiency is resolved by a corresponding architectural capability. The tertiary evaluation instrument executed a formal Zachman completeness assessment, wherein all modeled elements were mapped onto a two-dimensional matrix crossing four architectural perspectives (Contextual, Business, System, and Technology) with the six 5W1H interrogatives (What, How, Where, Who, When, and Why). Matrix cells were evaluated against explicit structural criteria derived from the model's underlying elements: a cell is designated as covered when at least one modeled element or structural relationship explicitly resolves the interrogative at that perspective (such as DataObject elements resolving What at the System viewpoint, or Node and Device elements resolving Where at the Technology viewpoint); a cell is designated as partial when the interrogative can only be inferred indirectly from constructs serving distinct functions (such as process sequencing derived from Triggering relationships in the absence of explicit temporal attributes); and a cell is designated as weak when no modeled element, relationship, or attribute addresses the interrogative, necessitating constructs entirely absent from the model. Cells classified as partial or weak denote architectural coverage gaps (Iyamu, 2023; Sowa & Zachman, 1992). This evaluation rubric was executed by a single architectural analyst; while inter-rater reliability was not statistically calculated, the operational transparency of the rubric and the open availability of the model repository support independent replication. Finally, Stage 5 synthesized architectural findings into actionable governance recommendations and an phased implementation roadmap.

4. Results and Discussion

4.1 Results

4.1.1 Architecture Vision (Phase A)

The architectural formulation initiates with the Architecture Vision, establishing the strategic consensus between township stakeholders and the target enterprise architecture, thereby resolving RQ1. Figure 2 delineates the structural alignment linking five primary stakeholder groups—executive township leadership, on-site estate management personnel, residents, commercial tenants, and external service and facility partners—to six strategic organizational goals: enhancing resident satisfaction and retention, maximizing operational efficiency, ensuring community safety and controlled access, expanding recurring service monetization, broadening the township commercial ecosystem, and establishing data-driven estate governance. Each strategic goal is realized through designated operational resources: a central township digital platform supporting operational efficiency and billing workflows; cloud hosting infrastructure providing elastic compute capacity; a resident mobile application driving satisfaction and service reach; an integrated IoT access-control infrastructure securing physical premises; and predictive analytics engines paired with unified tenant databases enabling evidence-based administration. Furthermore, each goal materializes into measurable target outcomes, translating strategic aspirations into verifiable operational metrics. Evaluated vertically from bottom to top, the motivational architecture establishes an unbroken chain of traceability connecting capital investments directly to overarching stakeholder concerns. Two primary architectural decisions are noteworthy within this motivational model. First, community safety and secure access are formalized as foundational strategic goals rather than peripheral operational additions, ensuring that access control and incident response propagate as inherited requirements across all lower architectural layers (Park *et al.*, 2021). Second, mapping each strategic objective to an explicit technological resource provides estate leadership with an effective governance mechanism, enabling capital expenditure proposals to be evaluated strictly by their measurable contribution to established organizational capabilities.

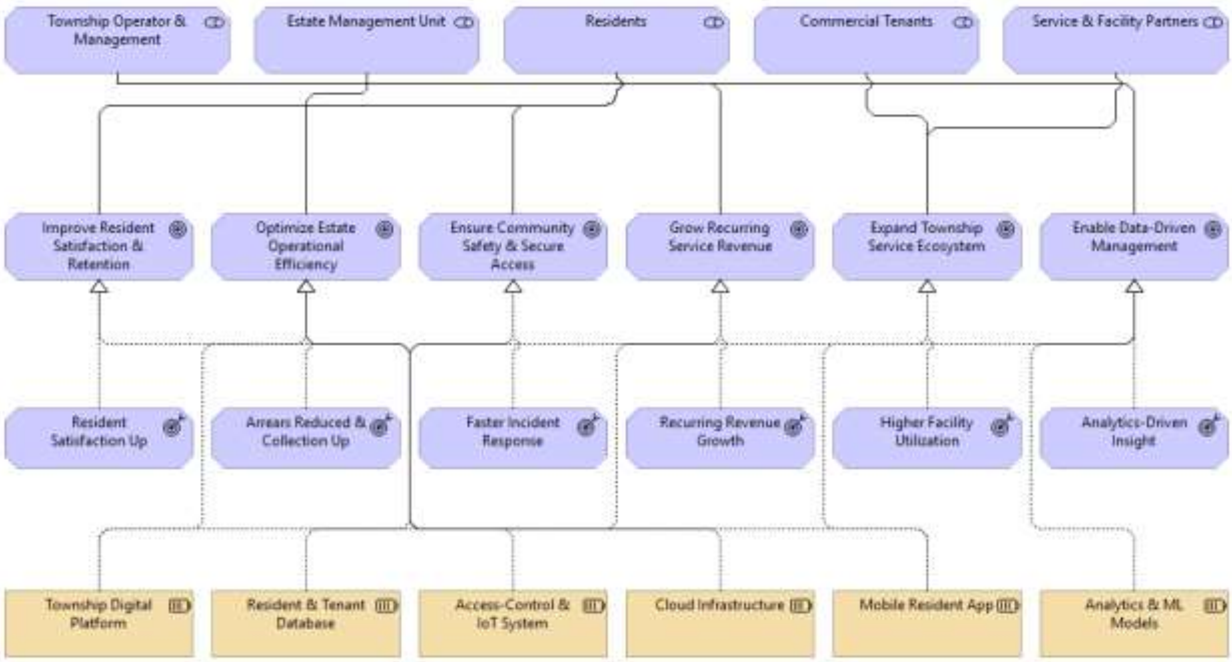

Figure 2. Architecture Vision aligning five stakeholder groups with six strategic goals, their outcomes, and enabling resources.

4.1.2 Business and Information Systems Architecture (Phases B–C)

The strategic intent defined in Phase A is operationalized across three core operational processes, each modeled continuously from initiating business actors through intermediary application services down to underlying data stores and hosting nodes, thereby resolving RQ2. Explicitly formalizing these end-to-end chains provides the structural foundation for subsequent completeness evaluation. The initial process, depicted in Figure 3, governs estate dues billing, which represents the operator's primary recurring-revenue stream. The workflow encompasses resident onboarding, automated invoice generation, payment gateway settlement, clearance verification, and subsequent general-ledger posting, with delinquent accounts routed through automated escalation workflows. Underlying this sequence are specialized application services: resident onboarding, a rules-based billing engine, payment gateway connectors, a centralized ledger service, and multichannel notifications. The billing engine and notification services maintain shared data access to centralized billing records, hosted upon the community core and payment application servers. This architectural pipeline demonstrates comprehensive vertical traceability, ensuring every discrete business activity corresponds directly to an identified software service, persistent data entity, and dedicated execution node.

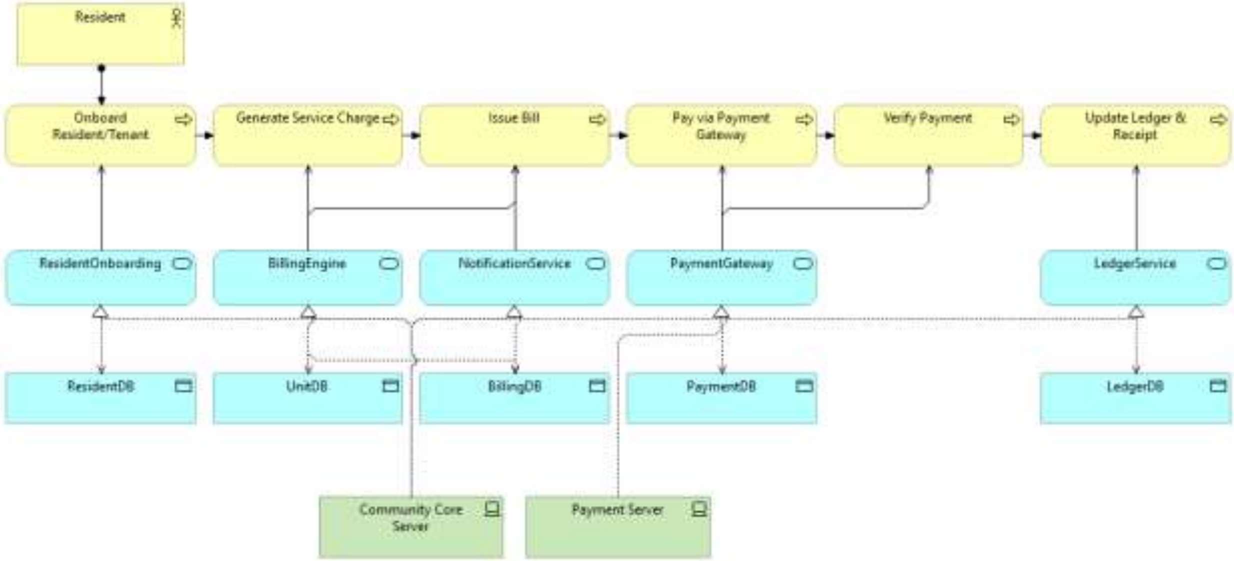

Figure 3. Estate dues and billing process architecture across the business, application, and technology layers.

The secondary process, facility reservation with smart access control (Figure 4), integrates the estate's cyber-physical systems into daily service workflows, fulfilling the strategic mandates for security and tenant convenience. When a resident initiates a reservation, the system validates facility availability and user entitlement, processes rental charges or quota deductions through the integrated payment gateway, confirms the reservation, and dynamically provisions encrypted digital access credentials. Physical admission is subsequently executed at automated turnstiles or smart readers, generating real-time audit logs. Supporting software services—comprising facility booking, quota validation, payment processing, access management, and telemetry logging—interact with facility, reservation, credential, and utilization data repositories deployed across community core and IoT gateway servers (Monios *et al.*, 2026; Sabit & Tun, 2024). A key design attribute is the deliberate reuse of the payment gateway service across both dues billing and facility reservations, ensuring unified financial reconciliation across disparate service lines.

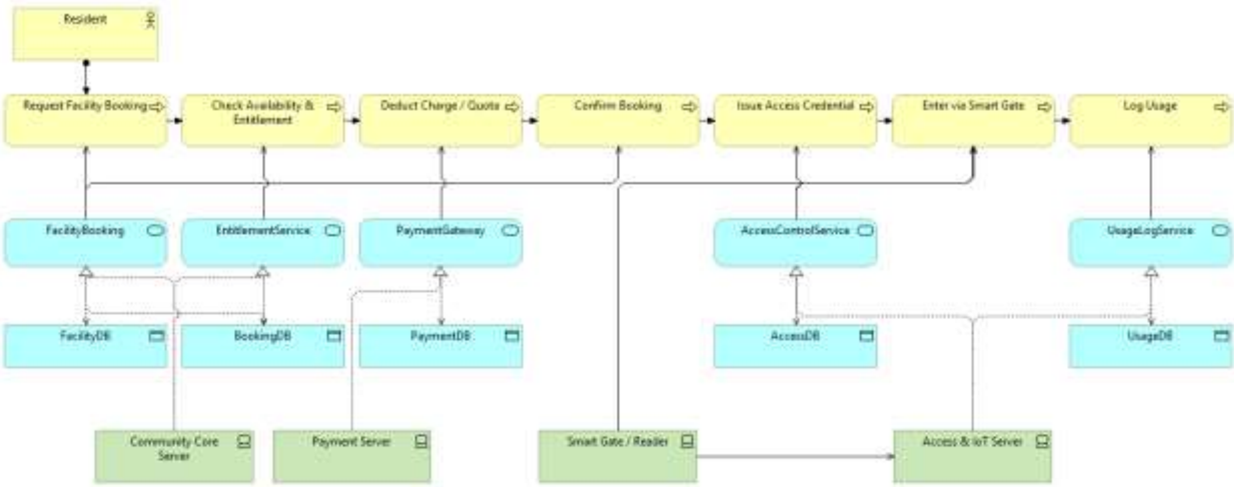

Figure 4. Facility booking and smart-access process architecture with IoT integration.

The tertiary process, resident service management and security response (Figure 5), unifies community administration with physical protection workflows. Upon receipt of a resident inquiry, maintenance complaint, or automated security alert, the platform performs algorithmic triage and dispatch, generating a field maintenance work order or mobilizing security personnel. Following on-site resolution, operational logs are finalized, and automated feedback requests are routed to the reporting tenant. Core application services—including service desk administration, work-order dispatch, incident response, and feedback aggregation—

manage persistent ticket, work-order, security incident, and survey datasets across community core and access-and-IoT servers. Collectively, these three operational workflows resolve RQ2 by establishing a deterministic mapping across business workflows, application components, data architectures, and infrastructure nodes, wherein shared services delineate natural functional seams within the integrated platform.

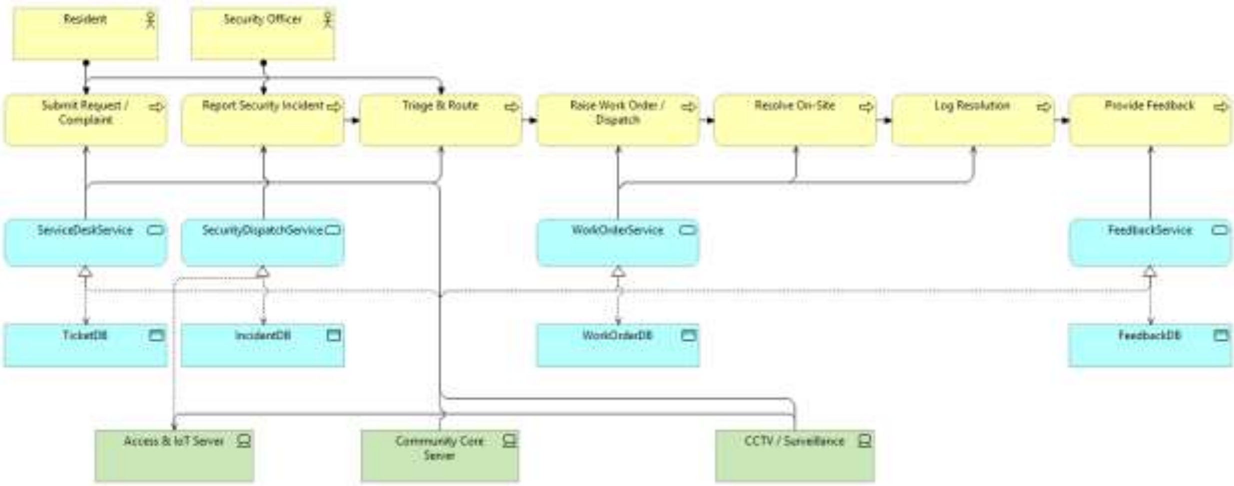

Figure 5. Resident service and security response process architecture.

4.1.3 Technology Architecture (Phase D)

Figure 6 consolidates the technology infrastructure into an integrated target deployment topology. External incoming traffic is managed through a multi-tiered security perimeter comprising enterprise firewalls, a Web Application Firewall (WAF), a Content Delivery Network (CDN) terminating Transport Layer Security (TLS), and an API Gateway that orchestrates service routing across the community core, payment, and access-and-IoT servers. These application servers persist transactional data within a high-availability relational database cluster, deployed entirely upon elastic public cloud infrastructure to ensure dynamic scalability without on-premise hardware provisioning (Lloret *et al.*, 2025; Monios *et al.*, 2026). The technology layer explicitly formalizes three external trust boundaries: the payment server interfaces with certified third-party payment gateways; the access-and-IoT server manages bidirectional communications with physical field devices, including automated gates, smart barriers, and surveillance nodes; and a dedicated integration bus connects external municipal and utility providers. Formally bounding these external interfaces replaces unmanaged third-party dependencies with governed integration contracts, substantially enhancing platform security and operational fault tolerance (Park *et al.*, 2021; Sabit & Tun, 2024).

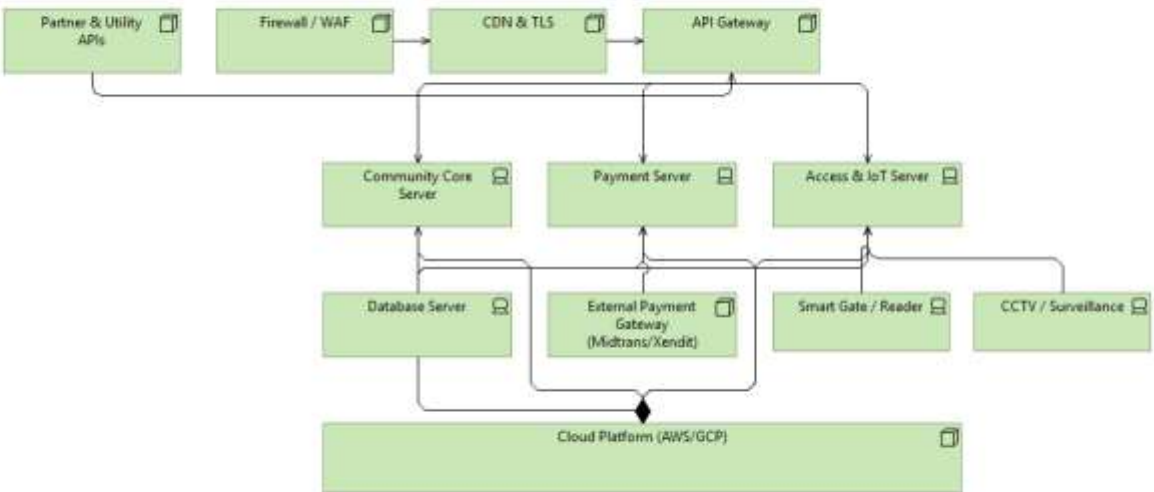

Figure 6. Target technology architecture with layered security ingress, dedicated servers, and governed external integrations.

4.1.4 Gap Analysis (As-Is Versus To-Be)

The resolution to RQ3 is established through a comparative gap analysis evaluating the fragmented As-Is operational baseline against the target To-Be enterprise architecture across each architectural stratum, as summarized in Table 2. Every documented operational deficiency in the baseline is directly resolved by a corresponding architectural capability within the target model, ensuring that no target component exists without an empirical justification. Concurrently, automated dependency tracing confirmed that all business activities are served by explicit application components, all application components interact with defined data entities, and all data repositories are realized through designated technological nodes, verifying complete structural integrity without dangling dependencies.

Table 2. Gap Analysis of the Smart-Township Enterprise Architecture

Layer	Baseline (As-Is)	Target (To-Be)	Gap / Solution
Business	Manual dues processing, unmoderated chat complaints, manual gate access logs	Standardized processes: onboarding, billing, facility booking, service desk, incident response	Formalized, repeatable workflows with integrated physical security governance
Application	Disparate point tools (spreadsheets, chat apps) lacking integration	Integrated core services (billing engine, reservation management, service desk) utilizing shared gateways	Consolidated application landscape establishing a single source of operational truth
Data	Transactional data scattered across personal devices, physical ledgers, and local files	Centralized domain databases (resident, billing, facility, access, incident logs)	Consolidated, consistent, and auditable enterprise operational data repository
Technology	Unmanaged personal devices; absence of dedicated enterprise infrastructure	Scalable cloud platform, API gateway, enterprise firewall/WAF, governed IoT network	Elastic, high-availability infrastructure with authenticated and encrypted integrations

As detailed in Table 2, the transition from As-Is to To-Be fundamentally restructures township administration from disconnected point tools into an auditable enterprise environment. By addressing operational vulnerabilities across all four architectural layers simultaneously, the design establishes the architectural coherence necessary to support reliable multi-tenant operations.

4.1.5 Zachman Completeness Assessment

Although gap analysis verifies that a target design resolves identified baseline deficiencies, it cannot evaluate absolute descriptive completeness, as an architecture might remediate all documented operational problems while omitting fundamental structural dimensions omitted from the baseline comparison. To resolve RQ4, all modeled architectural components were mapped onto a Zachman coverage matrix crossing four architectural perspectives with the six foundational 5W1H interrogatives, as presented in Table 3.

Table 3. Zachman 5W1H Completeness Matrix of the Smart-Township Architecture

Perspective	What (Data)	How (Function)	Where (Network)	Who (People)	When (Time)	Why (Motivation)
Contextual (Scope)	Core entities: resident, unit, dues, booking, incident	Core flows: billing, booking and access, service and security	Township estate; cloud and partner network	Stakeholders: operator, estate unit, resident, tenant, partner	Partial: recurring billing and booking cycles	Strategic vision, business goals, and measurable outcomes
Business (Conceptual)	Domain data objects (ResidentDB through IncidentDB)	Business processes (onboarding to billing; booking to access)	Service delivery points: digital platform, smart barriers, on-site personnel	Business actors (resident, security personnel) and stakeholder groups	Partial: process execution sequence via trigger relations	Strategic goals and target outcomes (motivation layer)
System (Logical)	Logical domain data models and schema definitions	Application services (billing engine through	Distributed application services across server clusters	Application services consumed by business actors and partner nodes	Partial: service orchestration and API call sequences	Strategic goals mapped to enabling operational resources

		dispatch service)				
Technology (Physical)	Relational database instances and cloud storage clusters	Processing nodes executing routing and policy enforcement	Cloud infrastructure and IoT network topology	External partner endpoints, payment gateways, smart gates, cameras	Weak: runtime latency, access validity windows, maintenance schedules	Layered perimeter security (WAF, TLS) and elastic cloud rationale

The matrix evaluation demonstrates a distinct coverage profile: of the 24 cells, 20 achieve full coverage, three exhibit partial coverage, and one is designated as weak. Five of the six interrogatives—What, How, Where, Who, and Why—achieve comprehensive coverage across all four architectural perspectives, accounting for the 20 covered cells. The architecture explicitly models the data entities managed, the functional behavior of processes and services, the spatial and network locations of hosting nodes, the participating human and system actors, and the strategic rationale governing system elements. Notably, the Why dimension achieves complete coverage due to the formal motivational architecture established in Phase A, an aspect frequently omitted in empirical enterprise architecture case studies. The Where dimension, while initially abstract at contextual levels, achieves complete specification within the Technology Architecture through formalized cloud networks, subnet topologies, and IoT communication links. Conversely, the temporal When dimension remains consistently underdeveloped across the architecture. Although ArchiMate Triggering relationships formalize procedural execution sequences, explicit temporal attributes—such as payment clearance settlement cycles, facility access validity windows, routine maintenance intervals, and contractual service-level response thresholds—are not formally modeled, accounting for all four non-covered cells. Two methodological factors clarify this outcome. First, this temporal shortfall represents an omission that conventional baseline gap analysis fails to identify, as manual baseline operations lack formal timing models for comparative benchmarking. Second, this limitation stems directly from the architectural scope boundary defined in Section 3.2. While ArchiMate 3.2 provides temporal modeling constructs within its Implementation and Migration Layer—specifically Plateau and Gap concepts (The Open Group, 2022a)—these entities model macro-level architectural roadmap transitions rather than runtime operational timing. Because the scope of this study was bounded at Phase D, these implementation constructs were excluded. Consequently, the completeness assessment successfully verifies architectural breadth while transforming an unmodeled operational dimension into an explicit empirical objective for future design iterations.

4.2 Discussion

The empirical findings advance enterprise architecture literature across two substantive fronts: domain application and evaluation methodology. Substantively, this research extends TOGAF-based architectural modeling beyond single corporate boundaries to the intermediate scale of operator-managed communities. Whereas Widjaja *et al.* (2025) focused narrowly on internal revenue workflows within a single property firm, the architecture developed herein formalizes complex workflows intersecting residents, commercial tenants, operational management, and external service contractors, thereby elevating shared software services and explicit trust boundaries to primary design concerns. Compared to the municipal smart-city frameworks proposed by Bastidas *et al.* (2022) and Yamamoto (2022), this study focuses on the operational purview of an accountable estate operator, where enterprise architectural investments directly impact an aggregated residential constituency. Furthermore, set against the point-solution cyber-physical designs of Sabit and Tun (2024) and Park *et al.* (2021), this study provides a complementary overarching foundation: while those prior works resolve specific hardware control protocols, this blueprint establishes functional requirements and operational rationales, linking technical components directly to business objectives. Table 4 positions this study relative to leading related works.

Table 4. Comparative Position of the Study

Feature	Widjaja *et al.* (2025)	Bastidas *et al.* (2022)	This Study
Domain Object	Single-firm real estate	Government-led smart city	Operator-managed master-planned township
Stakeholder Scope	Bounded corporate entity	Macro municipal population	Multi-stakeholder (operator, tenant, resident, partners)
Monetization Architecture	Partial internal revenue	Excluded from framework	End-to-end (dues, facility fees, auxiliary services)

Cyber-Physical / IoT Integration	Excluded	Conceptual discussion	Fully modeled (access control, barrier telemetry)
Applied Framework	TOGAF ADM + ArchiMate	Conceptual EA agenda	TOGAF ADM + ArchiMate + Zachman Framework
Completeness Assessment	Baseline gap analysis	Excluded	Formal Zachman 5W1H completeness matrix

As synthesized in Table 4, the proposed architecture provides comprehensive structural coverage across operational monetization, IoT integration, and multi-stakeholder governance, while introducing a formal completeness verification mechanism absent from prior literature. Methodologically, operationalizing the Zachman 5W1H interrogatives as an evaluative lens over a TOGAF–ArchiMate artifact demonstrated substantive empirical utility. The assessment uncovered a critical, non-obvious vulnerability—the under-specification of the temporal When dimension—which neither baseline gap analysis nor internal consistency checking could have surfaced, as both evaluate models against internal syntax or historical baselines rather than an absolute descriptive taxonomy. This outcome provides empirical validation for theoretical assertions regarding the synergistic alignment between taxonomic classification and procedural lifecycle frameworks (Iyamu, 2023; Reiter, 2025). Because the classification rubric is operationalized through deterministic rules and the underlying Archi model is archived, the evaluative mapping remains transparent and verifiable; establishing statistical inter-rater reliability across independent evaluators constitutes an objective for subsequent research. For township operators, the unmodeled temporal dimension entails direct governance implications: emergency response thresholds, dues billing settlement windows, and facility access schedules currently depend on local operating procedures rather than platform-enforced business logic. Consequently, explicit service-level attributes must be integrated prior to deploying contractual automation. Several boundaries frame the findings and suggest future research trajectories. The validation conducted herein is architectural and structural; while syntactic consistency and descriptive coverage have been rigorously confirmed, operational system performance awaits pilot deployment. Furthermore, because the artifact addresses a generalized township archetype, adopting operators must calibrate specific parameters to local regulatory and organizational environments. Finally, the completeness evaluation explicitly identifies operational temporal modeling as the primary limitation of the current design, defining a concrete agenda for subsequent engineering phases.

5. Conclusion and Recommendations

This study developed a completeness-driven enterprise architecture framework for integrated smart-township operations, combining TOGAF ADM to direct the design lifecycle, ArchiMate 3.2 to formalize cross-layer models, and the Zachman 5W1H interrogatives to provide an auditable coverage assessment within a Design Science Research paradigm. Regarding RQ1, the Architecture Vision successfully aligns five primary stakeholder groups with six strategic operational goals, each substantiated by dedicated technological resources, while formalizing community safety and access governance as core strategic objectives. For RQ2, three operational core processes—estate dues billing, facility reservation with smart access control, and resident service management with security response—were modeled continuously across the business, application, and technology layers, establishing modular integration seams through shared transactional services. Regarding RQ3, the comparative gap analysis confirmed that the target To-Be architecture directly resolves baseline fragmentation across business workflows, application silos, dispersed data repositories, and unmanaged IT infrastructure. For RQ4, the Zachman completeness assessment validated full structural coverage across the What, How, Where, Who, and Why dimensions across all four architectural perspectives, while isolating the temporal When dimension as the primary area requiring further development, thereby converting an architectural omission into an explicit operational roadmap. Based on these findings, three practical recommendations are formulated for township operators and enterprise architects adopting this blueprint. First, implementation should proceed through a phased deployment schedule that respects underlying architectural dependencies, prioritizing core resident onboarding and financial settlement gateways, followed by physical IoT access and incident response integration, and culminating in predictive analytics engines. Second, software engineering teams should adopt the delineated application service boundaries as candidate interfaces for modular microservice architectures, facilitating scalable cloud deployment and maintainability. Third, organizational governance must enforce cross-layer traceability, ensuring that subsequent functional feature requests are formally justified by verified contributions to established stakeholder goals. Future research will focus on formalizing the temporal dimension through operational service-level attributes and access scheduling, expanding the architectural scope into TOGAF ADM Phases E through G to address implementation governance, and validating the blueprint through empirical pilot deployments in live township environments to assess operational performance under real-world conditions.

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