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A Comprehensive Urban Health Architecture in Smart Living Using Smart City Architecture Development Framework (SCADEF)

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Abstract

In urban healthcare systems, rapid urbanization and population growth pose challenges, demanding creative approaches to deliver healthcare services efficiently and conveniently. With the global population projected to reach 68% urbanization by 2050, the need for integrated and citizen-centric healthcare solutions is increasingly pressing. This study develops an Enterprise Architecture for Smart Living using the Smart City Architecture Development Framework (SCADEF) to address service fragmentation and promote cross-domain interoperability. Applying a qualitative, design-focused methodology—through stakeholder interviews, expert reviews, and customer journey mapping—the architecture enhances service responsiveness, accessibility, and user experience. It integrates healthcare seamlessly into the broader Smart Living ecosystem. Importantly, the proposed architecture is modular and replicable by providing a scalable blueprint that can support other cities in modernizing their healthcare systems through the Smart Living concept. This contribution establishes a foundation for proactive, resilient, and sustainable urban health governance.

Keywords: Smart Living; Architecture; Comprehensive; Healthcare Integration; SCADEF; Urban Healthcare Systems;

1. Introduction

The rapid growth of cities has placed great stress on urban health systems and has required new methods for providing healthcare services at the expected levels of quality. As noted by United Nations (2019), urban dwellers are forecasted to reach around 68% of the global total of citizens by the year 2050, which will increase the need for more effective and coordinated healthcare systems that provide services with regard to the citizens' needs and centered around them. In this regard, Smart Living has developed as one of the key areas of smart city development focused on using technology to improve the quality of life in cities, especially concerning healthcare Mohammadzadeh *et al*, 2023). There is a clear shift towards adopting Smart Living solutions which indicates that technology is needed not only for the improvement of infrastructure, but rather, as a concern for public health as well.

Although smart cities are becoming prevalent, the provision of healthcare services in Smart Living is still fragmented. Major issues include gaps in coordination between public health and clinical services, disconnected health information systems, and a lack of provider interoperability (Mohammadzadeh et al., 2023). Such fragmented systems contribute to inefficiencies, delayed care, and negative patient experiences, underscoring the pressing demand for an all-encompassing integrated architectural blueprint for healthcare service optimization. For example, in several urban regions, the absence of integrated electronic health records has led to delays in emergency care, where paramedics lack real-time access to patients' medical histories, resulting in misinformed or delayed interventions (Mohammadzadeh *et al.*, 2023). Similarly, the lack of coordination between public health departments and clinical providers during the COVID-19 response highlighted critical gaps in data sharing and resource allocation (Kaluarachchi, 2022). These cases illustrate how disjointed digital health infrastructures can severely impact service delivery and public safety. In the absence of a unified framework for managing digital healthcare systems, metropolitan regions risk failing to meet the increasingly complex demands of their citizens in a rapidly evolving urban environment.

To address these gaps, defined approaches in Enterprise Architecture (EA) effectively assist in the alignment of organizational processes, information systems, and technology infrastructures, streamlining service delivery. Nevertheless, urban healthcare ecosystems' complexity, dynamism, and multi-stakeholder nature are traditionally difficult to incorporate within conventional EA frameworks. Smart city health contexts increasingly require

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flexibility, scalability, and interoperability; however, these traditional models tend to lack the adaptability to meet such demands (Bastidas *et al*., 2023). Enhanced service-oriented frameworks with greater agility are crucial in addressing The Living Healthcare integration challenges.

The SCADEF as smart city framework attempts to address all these requirements by proposing a system of systems approach for developing Smart City Architecture (Prasetyo & Habibie, 2022). In the smart living area, SCADEF outlines several management domains such as healthcare management, safety management, environmental management, and social services management. The healthcare management focus in SCADEF deals with the incorporation of diverse healthcare service provider networks, data exchange, interoperability, and cross-border comprehensive, strategic caring urban ecosystem navigation. With this integrated approach, SCADEF appears to provide a framework towards developing deep, enduring healthcare systems in smart cities.

Given this context, the research poses dual interrogatives: how to construct a fully integrated, comprehensive enterprise architecture framework model that accommodates healthcare integration within the Smart Living domain utilizing SCADEF, and how the proposed model stands in relation to existing architectural approaches discussed within the literature. This study's objectives are therefore twofold: (1) to design a Smart Living enterprise architecture model aimed at optimizing healthcare interoperability and enhancing service operational efficiency, and (2) to systematically evaluate the model, considering former enterprise architecture models for smart healthcare to expose its innovations, advantages, and limitations. Achieving these aims would advance urban health service integration and enable the formulation of more robust, citizen-centric smart city frameworks.

2. Related Works

Enterprise Architecture (EA) is a strategic framework that helps organizations align business goals, information systems, and technology infrastructure. In the context of smart cities, EA enables service integration, data interoperability, and system agility—particularly crucial in complex sectors like healthcare. Among the widely adopted EA frameworks is TOGAF (The Open Group Architecture Framework), which provides the Architecture Development Method (ADM) to guide the step-by-step design of scalable and interoperable systems.

Several studies have applied EA to the healthcare domain. Dharmawan *et al.* (2022) implemented TOGAF ADM to design an enterprise architecture for a hospital information system (SIMRS) at Rumah Sakit XYZ. Their research focused on the hospital's supporting services and demonstrated that EA can significantly improve system integration and reporting efficiency by generating artifacts such as business architecture, application architecture, and gap analysis. Similarly, Ikrima *et al.* (2023) applied TOGAF ADM 9.2 to design a Smart Village Enterprise Architecture focused on health services in Desa Pagerharjo, Indonesia. Their work incorporated services like maternal health monitoring, stunting reduction programs, and BPJS administration through an integrated application (SILAKes), aligning local public health efforts with national SDG goals.

However, most Smart Living studies still center around technical improvements or individual subsystems without offering a comprehensive, citizen-centered enterprise architecture. Oh (2024) focused on design strategies for elderly-friendly environments, while Youssef *et al*. (2024) proposed an interference management model to improve smart home IoT reliability. Stümpfle *et al.* (2023) presented a dynamic context-aware architecture using graph-based modeling, and Ouni and Saleem (2024) emphasized IoT-level security for ambient-assisted living. These studies, while valuable, are limited to single-layer optimizations and lack cross-domain orchestration, particularly in health-related services.

Other works like Darwish (2019) and Ngankam *et al.* (2019) proposed microservice-based and gateway-driven architectures for real-time smart living environments, but did not explore city-scale healthcare integration. Even Grguric *et al.* (2021), who analyzed European eHealth reference models, offered only a comparative classification without concrete implementation guidance. This reflects a consistent gap in the literature: the absence of an operational enterprise architecture model that positions healthcare at the center of Smart Living.

To address this gap, this study proposes a Smart Living Enterprise Architecture using the Smart City Architecture Development Framework (SCADEF). Unlike generic frameworks such as TOGAF or indicator-based models like SSCF-ITU/UNECE and IDEAL-CITIES, SCADEF offers three core advantages: (i) a value-chain–based service composition that integrates business, data, and technology layers; (ii) cross-domain orchestration that enables interoperability among health, environmental, and social services; and (iii) real-time, event-driven data integration suitable for urban health contexts (Prasetyo & Habibie, 2022).

By adopting SCADEF and aligning it with Design Science Research (DSR) methodology, this study contributes an integrated, modular, and scalable Smart Living healthcare architecture. It not only addresses technical fragmentation but also incorporates citizen journey mapping and service blueprints to ensure that healthcare services are user-centered and sustainable. This work builds upon and extends prior EA-based healthcare models by introducing a holistic, replicable blueprint for smart city health governance.

3. Research Design

This study adopts the Design Science Research (DSR) Framework as outlined by Sharda & Voß, n.d. to guide the structured development of a Smart Living enterprise architecture model focused on healthcare integration. The DSR framework emphasizes a problem-driven, iterative design process aimed at producing scientifically grounded and practically useful artifacts. As shown in Figure 1, the framework consists of five sequential stages: awareness of the problem, suggestion, development, evaluation, and conclusion.

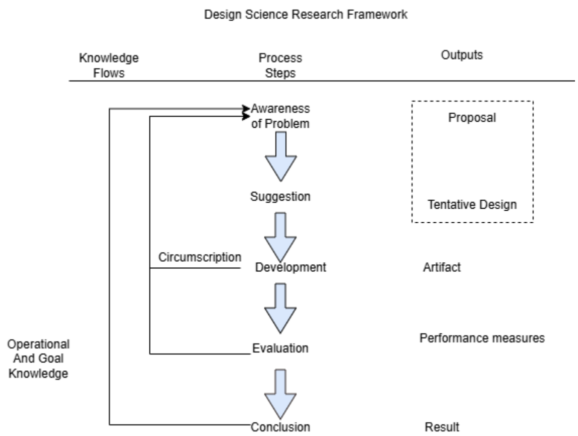

Figure 1 Design Research Framework (adopted from Vaishnavi and Kuechler (2007))

In the awareness of problem stage, the research identifies the fragmentation and lack of interoperability in urban healthcare systems as the central issue limiting the effectiveness of Smart Living initiatives. This finding is grounded in literature analysis and confirmed through discussions with local stakeholders.

The suggestion stage formulates a design-oriented solution: the need for a comprehensive, citizen-centered enterprise architecture that can align fragmented healthcare services and enable integrated service delivery in smart cities.

In the development phase, the proposed architecture is constructed as a design artifact. To support this phase, the research refers to the Smart City Architecture Development Framework (SCADEF) as a technical reference for structuring services and aligning architectural layers. Detailed modeling—including value chain identification, service integration points, and communication flows—is elaborated in the results section.

The evaluation phase involves validating the developed architecture through expert review and stakeholder feedback. Evaluation criteria include system interoperability, strategic alignment, implementation feasibility, and scalability in urban contexts.

Finally, in the conclusion phase, the results are synthesized to demonstrate how the developed architecture addresses the original problem. The study contributes not only a theoretically grounded model but also a practical reference for implementing integrated healthcare services in Smart Living systems.

The integration of SCADEF into the DSR cycle ensures that the artifact developed is both methodologically rigorous and technically grounded, with a specific focus on healthcare service orchestration. This dual-framework approach enables the model to address the practical challenges of fragmented healthcare delivery while aligning with theoretical standards in design research.

4. Results and Discussion

This section presents the results and discussion based on the structured stages of the Design Science Research (DSR) Framework. The analysis is oriented towards solving the main problem identified in the introduction—fragmented healthcare in urban Smart Living environments. Each phase of the DSR cycle contributes to the formulation, development, and validation of a proposed enterprise architecture to ensure an integrated and citizen-centric healthcare system in a smart city.

4.1. Result

4.1.1 Awareness of the Problem

Field observations and qualitative interviews with stakeholders, including representatives from BAPPEDA and the Health Office, revealed that despite the Smart Living initiatives in metropolitan areas, healthcare delivery remains fragmented, isolated, and less than fully responsive. Urban healthcare systems continue to operate under a disjointed framework, with limited interoperability and inadequate data exchange mechanisms. These findings confirm the core problem identified in the

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introduction: the absence of an integrated, adaptive, and citizen-centric healthcare infrastructure within the Smart Living ecosystem.

4.1.2 Suggestion

To address this problem, the study proposes the development of a Smart Living enterprise architecture that systematically integrates healthcare services through a service composition approach. This solution emphasizes cross-domain interoperability, real-time service coordination, and alignment with citizen needs. The architecture is designed to not only connect isolated municipal health systems but also to incorporate user experience through structured journey mapping. The conceptual direction of the solution is technically guided by the Smart City Architecture Development Framework (SCADEF), with details elaborated during the development phase.

While the architectural development follows SCADEF as a guiding framework, this study does not replicate it directly. Instead, SCADEF was adapted and extended in several critical ways to suit the unique challenges of Smart Living in the urban healthcare domain. Notably, the architecture introduces custom layering that embeds domain-specific APIs and service orchestration components, such as a Health Analytics and Monitoring Service (HAMS), sanitation-aware APIs, and real-time sensor data routing using MQTT. Furthermore, the study incorporates user journey blueprints and interaction mapping—elements not explicitly defined in SCADEF—to strengthen citizen-centered service responsiveness. These enhancements bridge the conceptual-technical gap in the original framework, enabling the proposed architecture to function as a practical and operational model for integrated Smart Living healthcare ecosystems.

4.1.3 Development

During the development phase, the proposed Smart Living architecture specifically for healthcare service management was designed using layered principles adapted from SCADEF to ensure service orchestration, technical interoperability, and user alignment. The main components developed include:

4.1.3.1 Value Chain Integration

This research focuses on the integration of healthcare services in the Smart Living framework to offer an interconnected and flexible service delivery model to city dwellers. Figure 2, the Value Chain, illustrates the core interactions that combine to create an integrated Smart Living ecosystem in which healthcare services reside at the center.

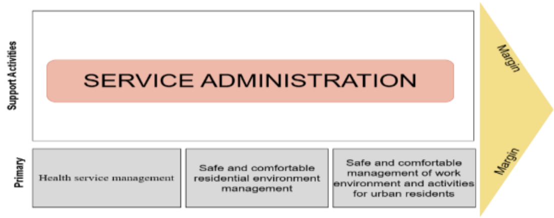

Figure 2 Smart Living Value Chain Model

The Value Chain within the Smart Living framework in Figure 2 encompasses a constellation of critical services, prominently featuring healthcare services. This integration guarantees that the applicable Smart Living technology meets the holistic requirements of a city dweller, especially concerning healthcare.

1. Primary Activities:

Strategic Healthcare Management: As the primary element of the value chain, this function covers integrated healthcare services including surveillance, diagnostics, treatment, and emergency services within the Smart Living paradigm. It is ensured that adaptive and constant support is provided for the resident's physical and cognitive health.

Management of Safe and Comfortable Residential Environment: This function guarantees healthy living conditions that pertain to safety and comfort along with the physical living environment. It includes the management of air as well as the ambient environment's lighting, temperature, and ergonomics which are crucial to urban dwellers, especially the aged and disabled.

Management of Safe and Comfortable Workplace and Activities: This function aims to maintain and promote health and safety in work settings smoothly integrated into the Smart Living system. It governs the interface between work activities and health in such a way that health risks are reduced.

2. Service Administration:

As illustrated in Figure 1, Service Administration is the top level that binds these activities into the Smart Living framework. It takes care of the services coordination and management in which healthcare, residential, and work services communicate with each other. It meets the needs of urban residents, enhancing their Smart Living experience, which is optimally automated and customized, especially regarding their health and safety needs.

Positioning health services management as a focal point of the value chain solves the problem of fragmented delivery of healthcare services, which is a hallmark of urban areas. With this model, healthcare is no longer an independent activity but instead a deeply integrated part of Smart Living, ensuring service interoperability and responsiveness spanning multiple urban systems.

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4.1.3.2 Designing Healthcare Services through Customer Journey Blueprint

The customer journey blueprint mapped out in Figure 3 shows the Smart Living interactions and important attention from the healthcare receive services perspective, primarily focusing on healthcare services within the life cycle. From the illustrative blueprint, it seeks to offer a citizen-based approach by recording the metropolitan residents' movements with regard, including their engagement with the services, towards the healthcare centers, specifically hospitals and health clinics.

This blueprint integrates the patient's perspective comprehensively and attempts to enhance intuitive access, user engagement, understanding and integration with other services offered within the metropolitan area. With the incorporation of Smart Living architecture and the customer journey blueprint, the research focuses on developing a holistic model which spans all the healthcare interactions from the first call to ongoing health monitoring, diagnostics, treatment, and even in emergencies.

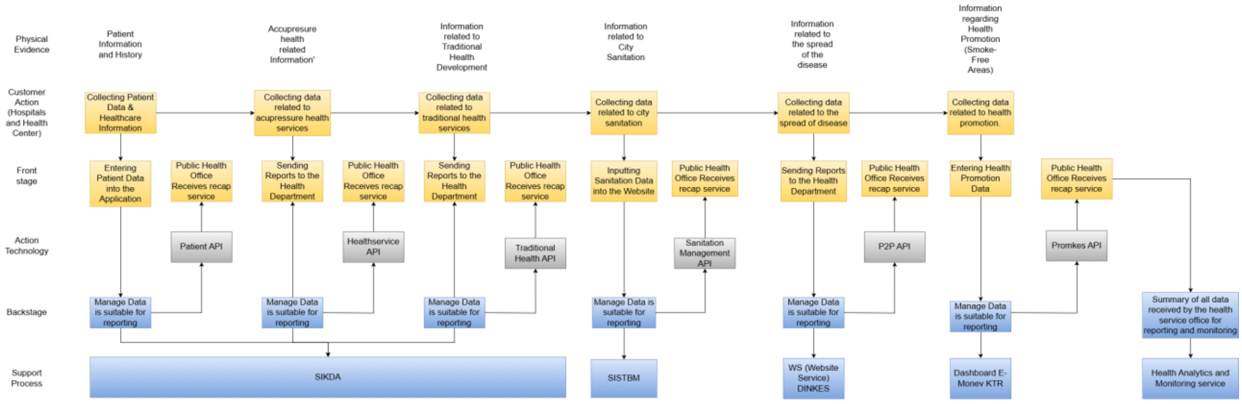

Figure 3 Smart Living Healthcare Service Blueprint Based on SCADEF Framework.

In Figure 3, it can be seen that the service blueprint has various phases which include patient data collection, health monitoring, treatment, and emergency response, along with an enclosed area that smoke-free zone that room which enhances the holistic model of healthcare delivery. Moreover, the blueprint also features acupressure health care and traditional healthcare, emphasizing the relationship of healthcare to the smart living ecosystem.

This also includes other supportive acupressure health services, traditional health services, and other sanitation services, which show the relationship of these health services to the broader smart living, smart living ecosystem. Providing healthcare services integrated with urban services such as sanitation and emergency services widens the perimeter of healthcare delivery as depicted in the blueprint under a conjoined structure approach to the city.

While many other approaches focus solely on the delivery of healthcare services, this is set apart by additionally integrating every step of the user experience. Integrating the customer journey blueprint into the smart living architecture allows alignment of healthcare services and citizens' needs such that smart cities will have responsive, effective, and complete healthcare services.

4.1.3.3 Smart Living Information Exchange Platform Design

To mitigate the continuing integration service fragmentation issues, the Smart Living Information Exchange Platform Bus architectural model, highlighted in Figure 4, is proposed in this research (Aladwan *et al.*, 2018; Prasetyo & Habibie, 2022) This model serves as a consolidated middleware layer that facilitates the interactions of the SIKDA (Sistem Informasi Kesehatan Daerah, an integrated health information system for regional health data management), SISTBM (Sistem Informasi Sanitasi Total Berbasis Masyarakat, a platform supporting community based sanitation surveillance system), WS Dinkes (Web Service platform enabling health data exchange across health agencies), and E-Monev KTR (evaluating and monitoring non-smoking area enforcement application) as core municipal applications with upper layer APIs and analytic components. This model and the unrestricted bus structure permit cross-domain policy-based service composition while avoiding direct system-to-system linkages, enabling enhancement of modularity and scalability. The Information Exchange Platform, with its modular attributes, coupled with centralized routing, facilitates diverse municipal services interoperability and ensures system-wide interconnectedness, thus fundamentally guaranteeing service scalability.

The model sets itself apart with the capability to decouple functional APIs, such as Patient API, Health Services API, Sanitation Management API, and P2P API from particular back-end systems. This decoupling allows particular services to change independently while achieving data coherence and interoperability. The architecture provides real-time information flow to the Health Analytics & Monitoring Service (HAMS) dashboard for multi-dimensional analytics, real-time policy enforcement,

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as well as automated and rational decision making by centralizing the routing and transformation through the platform bus.

Most importantly, this enhancement marks a transition from siloed, digitized services to a service-oriented, event-driven ecosystem in which responsiveness is enabled through coordinated orchestration and intelligent, lightweight data routing rather than system redundancy. This shift illustrates the evolution of Smart Living services from reactive and uncoordinated practices to proactive, integrated, and strategically cohesive operations governed under a unified enterprise architecture framework. These findings address the research question and provide actionable guidance for cities seeking to upgrade their service frameworks without compromising governance or limiting architectural agility.

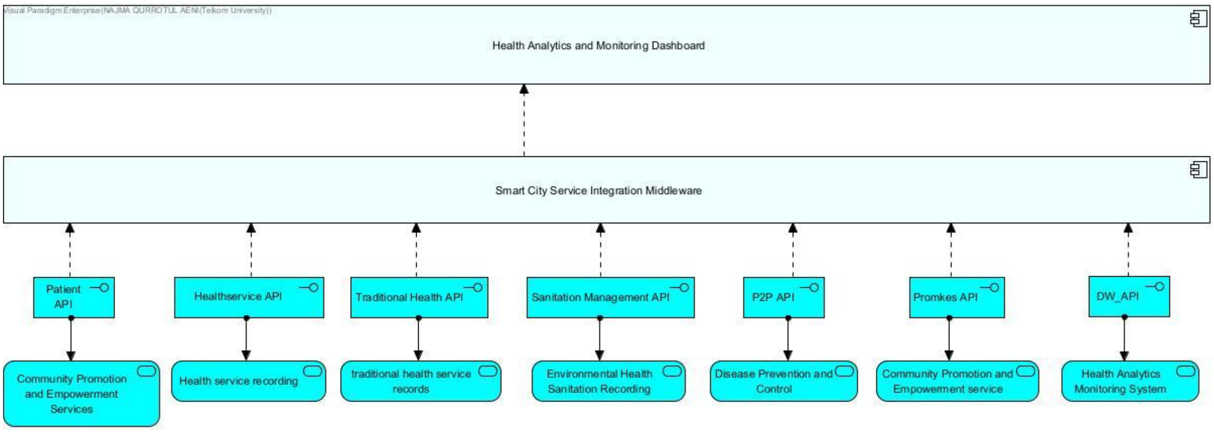

Figure 4 Enhanced Smart Living Information Exchange Platform Bus: Orchestrating data and service flows across municipal systems and analytics layers.

4.1.3.4 Application Communication Diagram

To achieve real-time, cross-domain service orchestration in the Smart Living ecosystem, an Application Communication Architecture of a multi-layered type was created. This architecture combines service-oriented architecture with modular service implementation for smart living applications and systems using an ESB based on message queues. The design follows the SCADEF framework enabling interaction of the urban IoT components, the city applications and the analytics services.

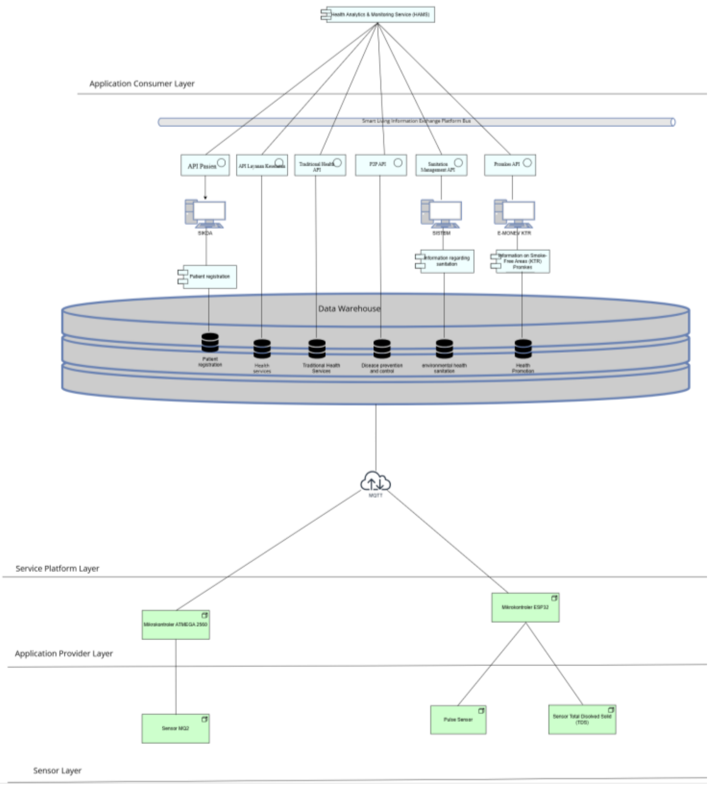

Figure 5 Application Communication and Sensor Architecture for Smart Living Services in an urban city in Indonesia.

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The system utilizes a layered framework to illustrate the flow of information processing from the physical world to the analytical services, as shown in Figure 5. In the Sensor Layer, health vitals, water sanitation, and air quality are monitored by the Pulse, TDS, and MQ-2 sensors, respectively. The sensors monitor data that is stored on the ESP32 and ATmega2560 microcontrollers. These microcontrollers make up the edge devices layer, or Microcontroller Layer, responsible for the preliminary data communication.

The readings collected from the sensors are shared through the MQTT protocol, which is perfectly suited for constrained networks due to its lightweight nature and reliable messaging architecture. Applications such as SIKDA, SISTBM, and WS Dinkes, heretofore cited in the service platform layer, process data in parallel, which add up to their respective servicing regional domains.

In addition, the smart living information exchange platform acts as the thick integration backbone enabling unrestricted information routing to specialized domain APIs for patients, health services including sanitation, and a data warehouse as defined in the application consumer layer. HAMS (Health Analytics & Monitoring Service) pulls together and snapshots the data horizontally across the services at the topmost level. This enables urban administrators and public health professionals to make data-driven decisions for the city.

The architecture focuses on service orchestration through an ESB-enabled structure, which allows for the integration and exchange of data across several urban services. By acquiring health, environmental, and overall urban service data through sensors and transmitting it in real-time, the system guarantees that this information is available to be processed and transformed meaningfully. ESB facilitates data routing and distribution to relevant service applications, employs a streamlined, citizen-centric model of service delivery, and enables efficient service automation. This approach goes beyond providing information and enables intelligent public health interventions while optimizing the strategic urban planning and governance.

4.1.3.5 Infrastructure and Data Layer Integration

A critical component in the realization of Smart Living. Creating seamless healthcare services requires that a strong and interoperable Infrastructure and Data Layer be designed. This layer is critical in uniting the front-end service systems with back-end information storage units, as well as in facilitating data transfers between healthcare institutions, municipal systems, and analytical platforms.

The Smart Living applications architecture as represented in Figure 6 consists of five structured layers which are, User Layer, Infrastructure Layer, Data Layer, Service Layer, and End User Layer. These layers articulate the overall operation of Smart Living Activities, which give tangible structures to the underlying principles.

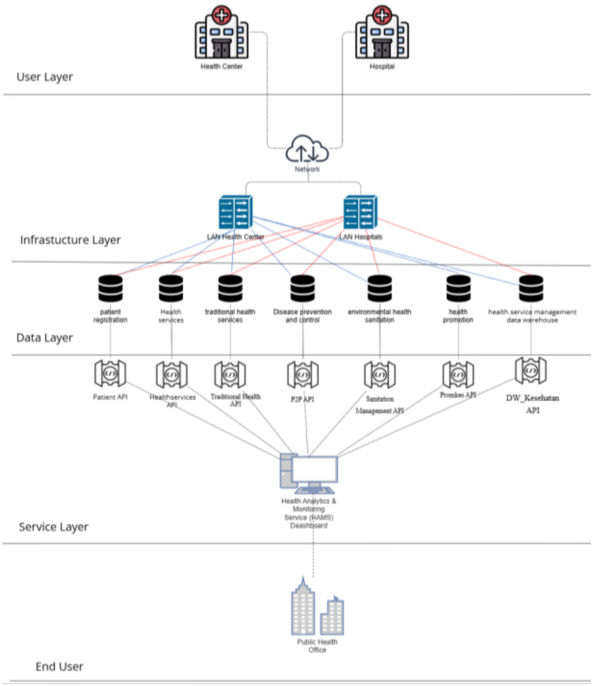

Figure 6 Infrastructure and Data Layer Architecture for Smart Living Services

Puskesmas and Rumah Sakit public health facilities serve as primary data collection sources at the Infrastructure Layer. These facilities are linked by a secure municipal network with cloud capabilities, supported by local health department data centers and servers. The implementations of cloud-native technologies provide scalability and resilience, whereas local computing nodes build the capability for situationally-dependent decision-making and operations with stringent latency requirements.

At the Data Layer, six categorized data repositories corresponding to different functional areas are outlined:

1. Patient registration
2. Health services
3. Traditional health
4. Disease prevention and control
5. Health promotion (KTR enforcement)
6. Centralized health service management data warehouse

Each repository is managed through application-specific APIs that are designed to handle distinct data types. These include the Patient API, which manages patient health records, and the Healthservice API, responsible for overseeing the delivery of healthcare services. Additionally, the Traditional Health API integrates alternative medicine practices, while the P2P API facilitates peer-to-peer communication between healthcare providers. The Sanitation Management API ensures that data related to sanitation and public health is appropriately handled, and the Promkes API focuses on health promotion and awareness programs. Finally, the DW API now enables data warehousing, guaranteeing the structured and fluid interrelationship of data across different systems and platforms.

The architecture employs one Smart Living Information Exchange Platform Bus as a middleware for safe and real-time application integration across different institutions. This bus performs data stream routing, transformation, and validation prior to the usage of the data by the upper-level services like the Health Analytics and Monitoring Service (HAMS). These analytical services assist with active monitoring, forecast-based epidemiology, and public health policy evaluation and intervention analytics.

4.1.4 Evaluation

To evaluate the capability of the proposed architecture in addressing the gaps identified in prior literature, this section assesses how the smart living enterprise architecture, specifically developed for urban healthcare integration, responds to the most pressing issues found in previous works. As shown in Table 2, the evaluation focuses on critical limitations such as fragmented healthcare delivery, lack of user-centered design, and the absence of scalable, city-level architectural models. By aligning each issue with corresponding architectural features, this checklist offers a structured validation that the proposed solution fulfills its intended contribution to citizen-centered, interoperable, and responsive smart living healthcare systems.

Table 1 Evaluation of the proposed Smart Living architecture

No	Critical issues in existing Approaches	Proposed Architecture	Solution
1	Fragmented healthcare systems without integration across services	☑	Developed an enterprise architecture using SCADEF and service composition principles to integrate healthcare, sanitation, and public health systems.
2	Lack of user-centered design and limited mapping of healthcare touchpoint	☑	Introduced customer journey blueprints to capture and design interactions between citizens and healthcare services at hospitals and clinics.
3	Absence of operational enterprise architecture for healthcare	☑	Designed a full-stack enterprise architecture covering business, service, and technology layers focused on urban healthcare domains.
4	Inability to support real- time data sharing and coordination among city health services	☑	Implemented an ESB-based communication model with MQTT protocol to enable real-time data flow among municipal systems.
5	Narrow focus on smart home or technical layers, lacking city-scale implementation	☑	Extended smart living design to city-scale by integrating municipal systems (e.g., SIKDA, SISTBM, WS Dinkes) into one shared platform.
6	Conceptual or theoretical models without implementation guidance	☑	Provided layered architecture, infrastructure models, APIs, and platform blueprint for implementable smart city healthcare architecture.

The results of this evaluation confirm that the proposed architecture effectively addresses the technical integration challenges that have limited previous Smart Living implementations, particularly in the healthcare domain. Beyond resolving issues of interoperability and service fragmentation, the architecture demonstrates the capacity to align healthcare services with the broader structure of urban governance. This alignment supports the development of a more holistic, scalable, and citizen-centered Smart Living healthcare ecosystem that is better equipped to respond to complex public health needs in rapidly urbanizing environments.

4.1.5 Conclusion of Design Cycle

This study demonstrates that the proposed Smart Living enterprise architecture successfully addresses the core problem of healthcare fragmentation in urban environments. By aligning citizen needs with technical and institutional capabilities, the architecture provides a scalable and integrative model that strengthens healthcare delivery across domains. The solution goes beyond previous conceptual models by providing an implementable framework that is grounded in real-world system integration, public health objectives, and smart city readiness.

While the architecture is conceptually validated, future work should include real-world pilot implementations, expansion to broader domains (e.g., mental health, education), and advanced analytics using AI for predictive urban health interventions. Nonetheless, the developed artifact stands as a replicable foundation for Smart Living healthcare transformation aligned with Indonesia's urban modernization goals.

4.1.6 Expert Evaluation and Stakeholder Alignment

To assess the effectiveness of the proposed Enterprise Architecture design using the Smart City Architecture Development Framework (SCADEF) for the Smart Living domain in an urban city in Indonesia, an evaluative instrument was distributed to selected respondents. These included professionals certified in Enterprise Architecture and key stakeholders from the local Communication and Informatics Agency (Diskominfo). A total of 11 evaluative indicators were measured using a four-point Likert scale (1 = Strongly Disagree, 4 = Strongly Agree).

Table 2 Respondent

Role	Count	Background Expertise
Diskominfo Representative	1	Smart City Strategy, Public sector ICT Policy, digital governance
Certified EA (Enterprise Architect)	6	Professionals with formal EA certification expertise includes IT master planning, system integration, business process modeling, smart city architecture design, and government digital transformation advisory
Total	7	

Each indicator corresponds to a critical phase in the SCADEF framework, such as Smart City Model Identification, Data Architecture, Service Architecture, and Strategic Alignment. The responses were analyzed using the following scoring formula:

$$Total\ Skor = (f_4 \times 4) + (f_3 \times 3) + (f_2 \times 2) + (f_1 \times 1)$$

$$Total\ Skor = (f_4 \times 4) + (f_3 \times 3) + (f_2 \times 2) + (f_1 \times 1)$$

Where:

f_4 = number of respondents who answered "Strongly Agree"

f_3 = number of respondents who answered "Agree"

f_2 = number of respondents who answered "Disagree"

f_1 = number of respondents who answered "Strongly Disagree"

Total Score = weighted sum of responses

Table 3 Summary of Evaluation Results

Indicator	Mean Score
Smart City Model Identification	3.4
Business Services and Process Modeling	3.1
Data Architecture	3.4
Service Architecture	3.3
Information Technology Architecture	3.3
Compatibility with Global Frameworks (e.g., TOGAF, ArchiMate)	3.6
Responsiveness to Local Government Needs	3.4
Integration with TOGAF	3.3
Interoperability Support	3.3
Scalability for Urban Service Delivery	3.2
Digital Transformation Alignment	3.4
Overall Mean	3.32

The results confirm strong agreement among experts on the clarity, adaptability, and strategic relevance of the proposed architecture. With a cumulative score of 259 and an overall mean of 3.32, SCADEF is validated as a responsive, scalable, and context-appropriate framework for Smart Living.

Reinforced by stakeholder input, the findings underscore SCADEF's readiness for real-world adoption and its potential to serve as a replicable model for integrated smart city development in Indonesia.

4.2 Discussion

The results of this study confirm that the Smart Living Enterprise Architecture developed through the DSR framework directly addresses the core problem of fragmented healthcare services in urban environments, as stated in the introduction. By placing healthcare at the center of the Smart Living value chain and aligning services through a service-oriented modular architecture, the model bridges disconnected systems and enhances interoperability across domains. The use of the SCADEF framework and service composition principles enables structured orchestration of services, not only in healthcare but also in supporting areas such as housing, sanitation, and public safety.

One of the most significant contributions of this study lies in translating Smart Living principles into a practical and executable architecture. While previous studies have often been conceptual or limited in scope, this study produces a city-scale framework that is based on real-world city system requirements. The integration of MQTT-based sensor communications, ESB-enabled service routing, and modular API components are examples of a technically robust and citizen-centric design approach.

The strength of this architecture lies in its layered integration—from data acquisition using IoT sensors, to middleware orchestration via the Smart Living Information Exchange Platform Bus, to application-level analytics via the Health Analytics and Monitoring Service (HAMS). These components enable real-time decision-making, personalized service delivery, and cross-agency coordination—all of which are critical for responsive urban healthcare governance.

In addition, the model demonstrates its scalability and replicability by demonstrating alignment with national digital health standards and adaptability to different urban contexts. The model offers a replicable blueprint for other Indonesian cities looking to transform their healthcare services within the Smart Living ecosystem.

However, the study acknowledges that the architecture has not been fully implemented in real-world urban settings. Its implementation is currently limited to select healthcare and public sector domains. Future research should focus on extending this architecture to broader service areas, including mental health, education, and urban resilience systems. Validation through real-world pilot projects, stakeholder co-creation workshops, and AI-enhanced analytics within HAMS will further strengthen its practical value.

Essentially, this research redefines Smart Living not just as a vision, but as a structured enterprise framework capable of operationalizing complex urban services. The proposed design establishes dual alignment: technically, through standards such as

MQTT and REST APIs; and institutionally, through an inter-agency governance structure embedded in the ESB. This innovation enables faster public service response, integrated policy implementation, and sustainable health system governance in smart cities. As such, this architecture is a significant step towards realizing a truly citizen-centric and integrated Smart Living ecosystem for Indonesia and beyond.

5. Conclusion

Through systematic evaluation and architectural modeling, this research arrives at the Smart Living Enterprise Architecture as a solution—combining the SCADEF framework with a service composition method—that mitigates the fragmentation of Smart Living services in urban areas. Furthermore, incorporation of real-time sensor data into municipal applications via an application-level Enterprise Service Bus (ESB) architecture enables modular, composable, and agile cross-domain service orchestration spanning healthcare, housing, and environmental services.

The architecture aligns with the study's goals and provides a practical and theoretical contribution toward the Smart City framework operationalization by enabling strategic and scalable pathways toward digital change. To broaden its usefulness, however, the architecture needs to undergo validation through expert evaluations by Subject Matter Experts (SMEs) and professional enterprise architects. Evaluation of architectural integration, execution, scalability, and security compliance with real-world constraints should be based on methodologies like the Delphi technique, structured focus group discussions, or other participatory design methods.

Limitations acknowledged in the current study include validating the design at the prototype stage and having a narrow initial domain focus. Moreover, addressing the architecture's extension into additional domains like education, mental health services, and comprehensive validation encompassing performance, risk, and expert evaluation is crucial for future research.

In attending to such aspects, the design can be optimized to function as an integrative, protective, and flexible underpinning framework for Smart Living ecosystems across different urban environments.

Bibliography

Aladwan, F., Alzghoul, A., Ali, E. M. M., Fakhouri, H. N., & Alzghoul, I. (2018). Service Composition in Service Oriented Architecture: A Survey. *Modern Applied Science*, *12*(12), 18. https://doi.org/10.5539/MAS.V12N12P18

Bastidas, V., Bezbradica, M., Bilauca, M., Healy, M., & Helfert, M. (2023). Enterprise Architecture in Smart Cities: Developing an Empirical Grounded Research Agenda. *Journal of Urban Technology*, *30*(1), 47–70. https://doi.org/10.1080/10630732.2022.2122681

Bouloukakis, G., Zeginis, C., Papadakis, N., Magoutis, K., Christodoulou, G., Kosyfaki, C., Lampropoulos, K., & Mamoulis, N. (2023). SmartCityBus: A platform for smart transportation systems. Proceedings of the 16th ACM International Conference on Web Search and Data Mining (WSDM 2023), 1299–1300. https://doi.org/10.1145/3539597.3575781

Darwish, R. R. (2019). Towards a congestion-aware sensor-cloud gateway architecture for real-time smart living applications. *Ad-Hoc and Sensor Wireless Networks*, *45*(1), 139–175.

Grguric, A., Khan, O., Ortega-Gil, A., Markakis, E. K., Pozdniakov, K., Kloukinas, C., Medrano-Gil, A. M., Gaeta, E., Fico, G., & Koloutsou, K. (2021). Reference architectures, platforms, and pilots for european smart and healthy living—analysis and comparison. *Electronics (Switzerland)*, *10*(14), 1616. https://doi.org/10.3390/electronics10141616

Halicka, K., & Surel, D. (2022). Smart Living Technologies In The Context Of Improving The Quality Of Life For Older People: The Case Of The Humanoid Rudy Robot. Human Technology, 18(2), 191–208. https://doi.org/10.14254/1795-6889.2022.18-2.5

Hevner, A. R. (2007). A three cycle view of design science research. Scandinavian Journal of Information Systems, 19(2), 87–92.

Ikrima, K. N., Fajrillah, A. A. N., & Nurtrisha, W. A. (2023). Enterprise architecture sebagai strategi pengembangan smart village pada dimensi health services. Jurnal Ilmiah Teknologi Sistem Informasi (JITSI), 4(3), 101–109. http://jurnal-itsi.org

Kaluarachchi, Y. (2022). Implementing data-driven smart city applications for future cities. Smart Cities, 5(2), 455–474. https://doi.org/10.3390/smartcities5020025

Mohammadzadeh, Z., Saeidnia, H. R., Lotfata, A., Hassanzadeh, M., & Ghiasi, N. (2023). Smart city healthcare delivery innovations: a systematic review of essential technologies and indicators for developing nations. *BMC Health Services Research*, *23*(1). https://doi.org/10.1186/s12913-023-10200-8

Moura, F., & de Abreu e Silva, J. (2021). Smart cities: Definitions, evolution of the concept, and examples of initiatives. In W. L. Filho, A. M. Azul, L. Brandli, A. L. Salvia, & T. Wall (Eds.), Industry, innovation and infrastructure (pp. 989–997). Springer. https://doi.org/10.1007/978-3-319-95873-6_6

Naccarelli, R., Casaccia, S., Pirozzi, M., & Revel, G. M. (2022). Using a smart living environment simulation tool and machine learning to optimize the home sensor network configuration for measuring the activities of daily living of older people. Buildings, 12(12), Article 2213. https://doi.org/10.3390/buildings12122213

Ngankam, H. K., Pigot, H., Parenteau, M., Lussier, M., Aboujaoudé, A., Laliberté, C., Couture, M., Bier, N., & Giroux, S. (2019). An IoT Architecture of Microservices for Ambient Assisted Living Environments to Promote Aging in Smart Cities. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *11862*, 154–167. https://doi.org/10.1007/978-3-030-32785-9_14

Oh, M. (2024). Importance of Design in Smart Digitalization: Smart Living Environments for the Aging Korean Elderly. *Buildings*, *14*(12). https://doi.org/10.3390/buildings14123748

Ouni, R., & Saleem, K. (2024). Secure smart home architecture for ambient-assisted living using a multimedia Internet of Things-based system in smart cities. *Mathematical Biosciences and Engineering*, *21*(3), 3473–3497. https://doi.org/10.3934/mbe.2024153

Prasetyo, Y. A., & Habibie, I. (2022). Smart City Architecture Development Framework (SCADEF). *International Journal on Informatics Visualization*, *6*(4), 869–875. https://doi.org/10.30630/joiv.6.4.1537

Putra, S. W., & Hendrato, H. (2021). Liaison Journal of Engineering Alat Berupa Prototipe Untuk Mendeteksi Asap Rokok Melalui Sensor Mq-2 Berbasis Arduino Mega 2560. 1(1).

Santiago, A. R., Pineda-Brise±o, A., Gonzalez-Rodriguez, J. A., & Huerta, U. S. (2020). Smart Environments for assisted living: A multidisciplinary collaboration in engineering and architecture education. *ASEE Annual Conference and Exposition, Conference Proceedings*, *2020*, 1238. https://doi.org/10.18260/1-2--35194

Stümpfle, J., Sahlab, N., Kamm, S., Grimmeisen, P., Jazdi, N., & Weyrich, M. (2023). InteLiv: An Architecture for Graph-Based Dynamic Context Modeling for Smart Living. *IEEE International Conference on Emerging Technologies and Factory Automation, ETFA*, *2023*, 2023. https://doi.org/10.1109/ETFA54631.2023.10275388

Syed, A. S., Sierra-Sosa, D., Kumar, A., & Elmaghraby, A. (2021). Iot in smart cities: A survey of technologies, practices and challenges. Smart Cities, 4(2), 429–475. https://doi.org/10.3390/smartcities4020024

Youssef, H. M., Osman, R. A., & El-Bary, A. A. (2024). Efficient Connectivity in Smart Homes: Enhancing Living Comfort through IoT Infrastructure. *Sensors*, *24*(9). https://doi.org/10.3390/s24092761