JOIV : Int. J. Inform. Visualization, 6(4) - December 2022 869-875

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage : www.joiv.org/index.php/joiv

Smart City Architecture Development Framework (SCADEF)

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***Abstract*— Smart City is a city that implements the latest technologies, such as big data, IoT, Artificial Intelligence, and other new technologies. Smart City has different system characteristics than other systems. Smart City involves several independent stakeholders, so the development of a smart city needs to be designed with a system analysis system and service-based planning. Smart City Architecture Development Methodology (SCADM) has been defined from the previous research. However, the existing Enterprise Architecture approach has yet to specify the artefact to complete the framework. This study recommends the Smart City Architecture Framework (SCADEF) as a comprehensive Enterprise Architecture Framework to develop Smart City Architecture. The architecture framework produced by SCADEF becomes the proposed architecture framework for realizing Smart City. SCADEF consists of SCADM, Meta-model Smart City Architecture Development Methodology Artefact, and guidelines by the implementation SCADEF. The research uses observation, classification, and construction methodologies in Information System Design Methodology. In addition, this study also tested the framework by implementing it on city objects. This implementation is a practical test tool for the resulting enterprise architecture framework. This study implemented SCADEF in the education and health field at Bandung Smart City. Implementing testing on the implementation of SCADEF is to explain the implementation in Bandung Smart City and ask for an assessment from enterprise architecture experts. The results of the expert assessments were calculated statistically to assess the methodology, artefacts, and uses. The measurement results show that SCADEF can be accepted and used to develop enterprise smart city architecture.**

***Keywords*— Smart city architecture; enterprise architecture framework; artefact meta-model.**

Manuscript received 11 Jan. 2022; revised 22 Mar. 2022; accepted 21 Apr. 2022. Date of publication 31 Dec. 2022.

I. Introduction

Smart City has different characteristics from companies with a sub-system as a distributed system and must collaborate to support its implementation [1]. In addition, several recent studies proposed several new layers or perspectives in the use of the enterprise architecture framework (EAF) for use in Smart Cities, including the Service layer [2], Stakeholder Perspective [3], Focus on Data Architecture [4], and focusing on technology architecture [5]. Smart City architecture needs to be developed with a comprehensive approach to the Enterprise Architecture approach. This approach follows the development of the Smart City sub-system, which creates independently but will need each other in their interactions.

Several previous studies have carried out the development of a framework for Smart City Architecture Development. Framework [2] enables cities to become standards and guidelines for implementing and managing Smart City Services. The Cisco Smart city framework: Smart City Framework, A Systematic Process for Enabling Smart+Connected Communities, enabling stakeholders to drive and test Smart City initiatives [3]. This framework has four layers that consider the city's social, environmental and economic objectives; city indicators measure and compare cities using predefined methodologies. [4] has compared three domains: business, information systems, and technology. In this comparison, the existing framework does not yet provide a complete and comprehensive approach to the Smart City architecture development framework. SCADM has been developed as a thorough methodology with a business domain approach, information systems, and technology using a meta-analysis of previous studies [5]. SCADM is a methodology developed to develop Smart City Architecture with a system of system and service-based approach for the characteristics of Smart City. This SCADM complements the more technical methods of the BSI framework [6] as a strategic guide for Smart City. Framework [7] proposed the improvement framework with Territorial Governance using GIS Technology.

The need for an alternative Architecture Development framework has become important for realizing The Smart City [7]. The existing SCADM requires an artifact meta-model to complement the Smart City Architecture Development Framework (SCADEF). The artifact meta-model will complete the SCADEF implementation guide for developing a Smart City architecture. The study provides recommendations for meta-model artifacts as part of SCADEF and their implementation in Bandung Smart City. The trial results will provide a complete description of the guidance and evaluation of the meta-model artifacts developed.

II. Materials and Method

A. Related Framework

An Enterprise architecture framework (EAF) is a blueprint for enterprise architecture, presents its content, and offers guidance and orientation accordingly significant [11]. EAF is needed to develop architectural designs and references to build Smart City, and the resulting architecture can be a reference for sustainable Smart City development. The development of the artifact meta-model is based on the artifact mapping results from previous studies. Therefore, one of the formulations of components and artifacts uses Table 1 mapping. Table shows research that recommends domains and artifacts for EAF Smart City development.

TABLE I
ENTERPRISE ARCHITECTURE ARTEFACT OF RELATED RESEARCH

Core Requirements	Architecture Domain (artifact)				
	Business	**Data**	**Application**	**Technology**	**Other**
[3]	Goal, Organization Unit				
[7]	Organization Unit	Data Entity	Application Portfolio	Technology Standard	
[8]			Application Portfolio, Interface Catalog		
[9]		Data Entity	Application Portfolio, Interface Catalog	Technology Standard	
[10]	Goal, Organization Unit		Application Portfolio	Technology Standard	
[2]	Vision & Strategies, Capabilities, Stakeholder Value	Data		Security & privacy	Governance: Funding and Metrics
[15]	Smart Service Model	Data	Application	physical layer: infrastructure, sensor	
[16]	Goal, Stakeholder Driver, City Service	Data Object	Application Process, Application Interface		
[17]	Stakeholder, Smart Services, Information Service	Data Entity			
[18]	Business Process	Big Data	Service Base, Distributed Computing, Smart City Application and Systems	Internet of Things	
[19]		Big Data, Service Oriented Architecture	Smart Application	Internet of Things, Network	
[20]		Data	Application	Sensor, Network	Security
[21]	Value Added Service, Stakeholder	Data	Application	Technology	
[23]	Stakeholder, Business Process, Business Service	Data	Application		Business Contract
[24]	Strategy, Business	Data	Applications	Infrastructure	Security
[25]	Stakeholder, City Service	Data Entities	Application	Infrastructure	Quality Factors
[26]	Business Service	Information	System Solution	Physical Resources	

B. Smart City Architecture Development Methodology (SCADM)

SCADM is a method to develop Smart City Architecture [5]. SCADM was formulated using a meta-analysis method. The stages and phases of SCADM can be seen in Fig. 1. It shows that SCADM consists of 4 stages: Initiation, Strategy, and Goal; Smart City Modeling; Smart City Design, and Evaluation.

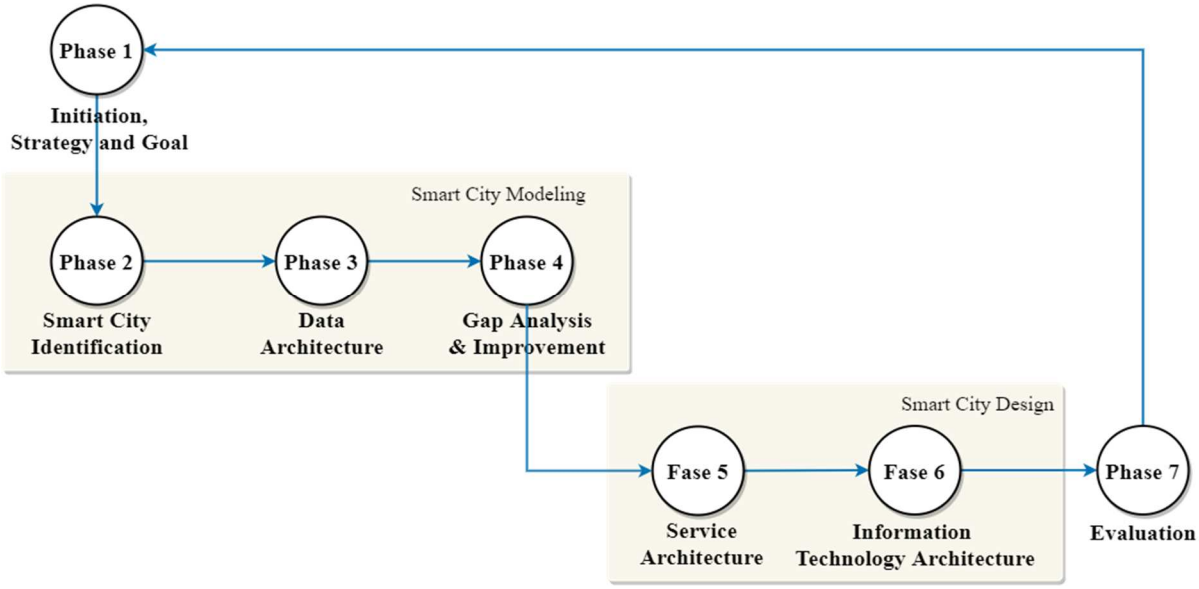

Fig. 1 SCADM Methodology

SCADM consists of 7 phases represented by a round shape. The seven phases of SCADM are [5]:

- Phase 1 Initiation, Strategy, and Goal: Initiation defines a plan to start smart city development in activity planning, scope, and teams involved in formulating smart city development. Strategy is formulating steps and the responsible parties during smart city development. Goal develops the objectives of implementing a smart city that can be measured and meet the aspects of the smart city goal.
- Phase 2 Smart City Model Identification: Through the identification phase, the information and data needed will be obtained to design the architecture of the smart city of an organization or city.
- Phase 3 Data Architecture: a phase to determine what data is needed in the research. This phase aims to identify how the data moves through the system and how the data is used.
- Phase 4 Gap Analysis & Improvement: This phase determines the steps to migrate from the current service condition to the desired service condition. Gap analysis aims to determine the ability to meet architectural needs as a reference in architectural development.
- Phase 5 Service Architecture: This includes designing service requirements to support smart cities. Its purpose is to design smart city service needs by the service needs provided to consumers.
- Phase 6 Information Technology Architecture: This phase aims to design the needs to support information technology in the services that will be provided for the implementation of the smart city of Bandung.
- Phase 7 Evaluation: it is activities carried out to determine the value and feedback of the overall design. The methodology, framework, artifacts, and case studies are all considered through this phase.

C. *Research Methodology and Case Study Scenario*

The research methodology used is observation, classification, and construction [8], [9] of several Enterprise Architecture (EA) implementations. Observations were made by looking at related previous studies. Classification is to categorize and enter research results into associated categories. Construction is a step to form a relationship as a form of relation and the form of the relationship analysis, which is the SCADEF artifact meta-model. Furthermore, Implementing the framework to the case study will evaluate and improve the framework.

The implementation of SCADEF in the case study aims to test the framework with the pragmatic truth. Implementation of SCADEF in two subdomains of Smart City, namely Smart Health and Smart Education in Bandung City. Smart City is necessary to be implemented in cities in Indonesia, especially in Bandung, Indonesia. The city of Bandung has planned and launched the Bandung Smart City to make it happen [8].

A smart city is indeed a trend in Indonesia. Not only as a form of prestige to be called a "smart city", but a smart city is a great step in advancing cities in a country based on Information and Communication Technology (ICT). A smart city is indeed defined as a smart city with a concept designed to create an efficient and effective smart health concept for the community, especially in the management of health services. Smart Cities, also known as digital and virtual cities, are expected to overcome the complex challenges of today and the future in increasing resource efficiency, reducing spending, maintaining health services for the elderly, and integrating minorities. Reference Architecture has become important in designing an organization's Information Technology (IT) system. The domain needed in developing the smart city observation approach architecture is by using Enterprise Architecture (EA). Several studies have been published in recent years on the development of smart city architecture. However, there is still a lack in developing smart city architecture's reference. Some research has been held by some researchers previously.

III. Results and Discussion

A. *Meta-Model Artefact*

Architectural Artefacts describe in detail how the underlying meta-model can be used to present a set of

catalogs, matrices, and diagrams to address stakeholder concerns. Artifacts are beneficial for describing architectural features from a specific point of view (network diagrams, server specifications, architectural requirements list, and business interaction matrices). The following are the artifact groups [27]:

- Catalogs are lists of building blocks of specific types used for reference purposes.
- Matrices are tables that show the relationship between two or more entities.
- Models/Diagrams can be used to fill in architectural content graphically.

The research defines artifacts based on tables and comparisons of the use of artifacts in the practical world. Using the SCADM methodology, a framework called the Smart City Architecture Development Framework (SCADEF) can be produced. SCADEF can be used to compile smart city architecture information in an orderly manner starting from the initiation, strategy, and goal phases to information technology architecture. Therefore, it can be processed to meet the needs of stakeholders. A visual explanation of the SCADEF artifacts is in Fig. 2.

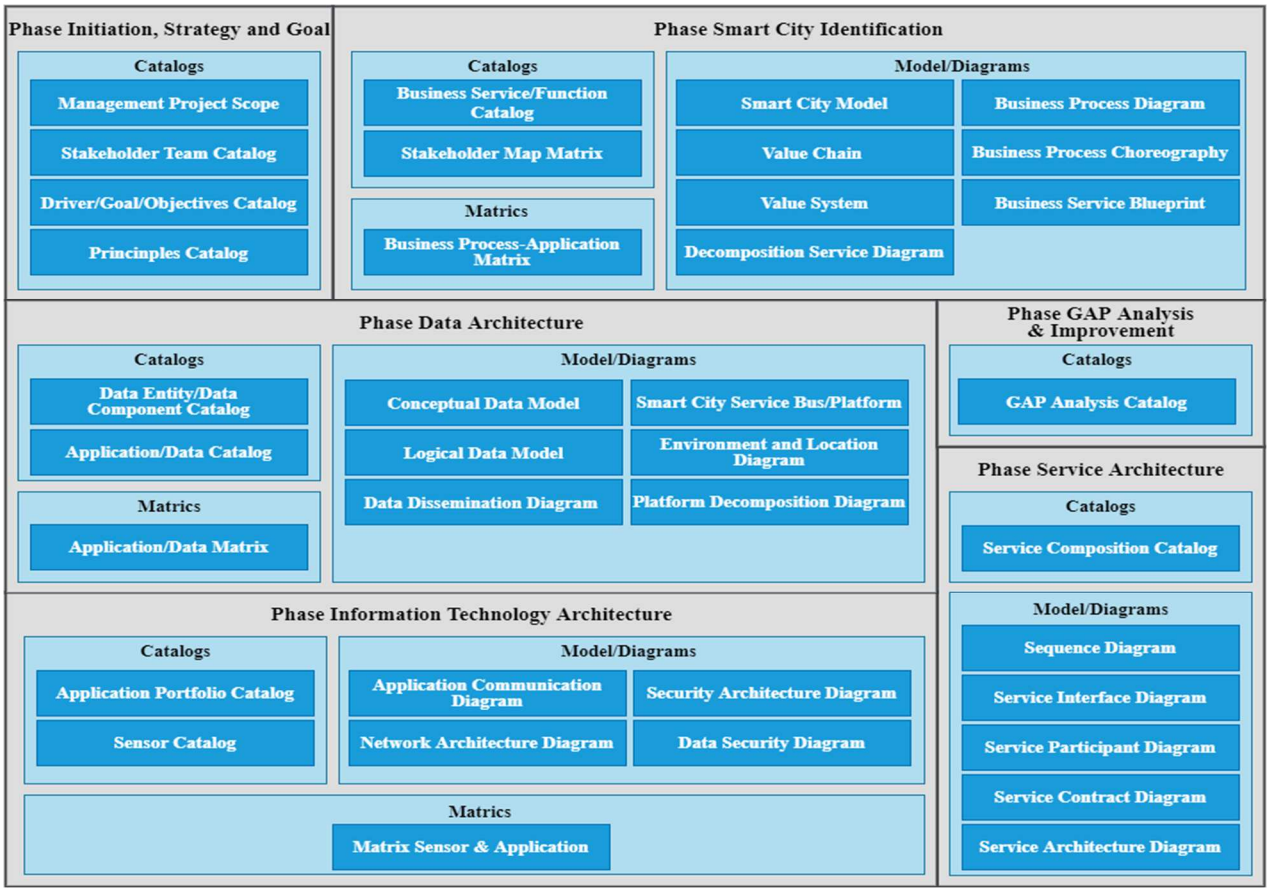

Fig. 2 Meta-model Artefact of SCADEF

B. *Case Study*

The implementation of the case study was carried out in the city of Bandung in the field of education as Smart Education and health as Smart Health. The Smart City Model for Smart Health can be seen in Fig. 3. The Smart City Model for Smart Education can be seen in Fig. 4. The scope of implementation of the Smart Health case study is in the blue section on Fig. 3, which includes Disease Control Prevention, Health Surveillance, and Health Service Evaluation. The implementation of Smart Education in the city of Bandung includes the yellow section in Fig. 4, namely education operation and education monitoring and evaluation. SCADEF Artefact Development for Bandung Smart City can be seen in Table 2. The artifacts have been developed in Table 2, as defined in Fig. 2.

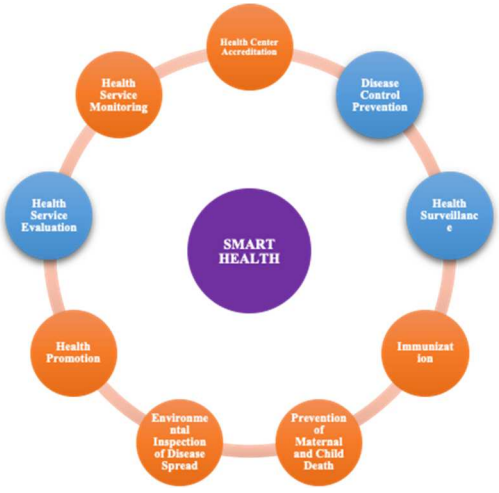

Fig. 3 Smart Health Model

Fig. 4 Smart Education Model

The artifacts were created according to the needs and plans for the future development of Bandung Smart City. The Smart City Model, Data Architecture, Service Architecture, and Information Technology Architecture artifacts will be the reference architecture for the design, development, and realization of Smart City in Bandung City. The number and type of Bandung Smart City architecture realized can be seen in Table 2.

TABLE II
ARTIFACT SCADM PHASE

SCADM Phase	Artifacts		
	Type	Smart Health	Smart Education
Initiation, Strategy, and Goal	Management Project Scope	Description	
	Stakeholder Team Catalog	Description	
	Driver/Goal/Objectives Catalog	1	1
	Principle Catalog	1	1
Smart City Model Identification	Smart City Model	1	1
	Value Chain	1	1
	Value System	1	1
	Business Service/Function Catalog	1	1
	Decomposition Service Diagram	1	1
	Business Process Diagram	11	12
	Business Process-Application Matrix	1	1
	Business Process Choreography	11	12
	Business Service Blueprint	10	11
	Stakeholder Map Matrix	1	1
Data Architecture	Data Entity/Component Catalog	1	1
	Conceptual Data Model	1	1
	Logical Data Model	1	1
	Application/Data Catalog	1	1
	Application/Data Matrix	1	1
	Data Dissemination Diagram	3	2
GAP Analysis & Improvement	GAP Analysis	Description	
	Recommendation	Description	
Service Architecture	Service Composition Catalog	1	1
	Sequence Diagram	36	11
	Service Interface Diagram	36	11
	Service Participant Diagram	3	2
	Service Contract Diagram	37	11
	Services Architecture Diagram	10	2
Information Technology Architecture	Application Portfolio Catalog	1	1
	Sensor Catalog	1	1
	Sensor & Application Matrix	1	1
	Network Architecture Diagram	3	2
	Data Security Diagram	1	1
	Security Architecture Diagram	3	2
	Application Communication Diagram	3	2
Evaluation		Description	

C. Evaluation

SCADEF evaluation is carried out using a focus group discussion approach to experts in the EA field. The criteria for expert participants include:

- have a minimum national EA certification,
- Implement EA in real cases.

Participants were given 14 statements to be assessed as follows in Table 3. The question consists of 4 parts, namely SCADEF, SCADM, SCADEF Artefact, and the results of the implementation of the case study. The statements consist of a Likert scale assessment.

TABLE III
LIST OF QUESTIONNAIRE STATEMENT

No.	Statement
Evaluation of the Smart City Architecture Development Framework (SCADEF)	
X1	The SCADEF have the clarity and completeness for designing Smart City architecture
X2	The SCADEF is easy to understand for designing Smart City architecture
X3	the SCADEF different from other enterprise architecture frameworks

No.	Statement
Evaluation of Smart City Architecture Development Methodology (SCADM)	
X4	The Smart City model identification phase in the SCADM method meet the needs of the business architecture
X5	The Data Architecture phase of the SCADM method met the needs of the data architecture
X6	The Service Architecture phase of the SCADM method helped realize a Smart City
X7	The Information technology architecture phase of the SCADM method helped realize the application architecture, sensor network and security
X8	The methodology is easy to understand
X9	Overall, The SCADM method easy to understand and can be used to realize a Smart City
SCADEF Artefact Evaluation	
X10	SCADEF Artefacts have the clarity and completeness to design Smart City architecture
X11	Are SCADEF artifacts easy to understand and use for designing smart city architectures?
Evaluation of Case Study Implementation	
X12	The SCADEF been successfully implemented in Smart Education/Health in Bandung
X13	The SCADEF makes it easy to design Smart Education/Health in Bandung
X14	The SCADEF is interesting to implement in other case studies similar to Smart City

The number of participants is as many as 24 people. Each participant was assessed on a scale of strongly disagree (1), disagree (2), agree (3), and strongly agree (4). From these results, the following values are obtained. Every score of each statement will be multiplied by 14 as the maximum number of questions. The value of the minimum population means an expected 42 as the agreed minimum score. The Table shows that the data is normal distribution by the mean of test value 42 with Sig. (2-tailed) score is 0,117, more than 0,05. It means SCADEF is agreed to be accepted as a framework for developing Smart City Architecture Framework.

TABLE IV
NORMALITY TEST RESULTS

One-Sample Test						
	Test Value = 42					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Sum Answer	1,630	23	0,117	1,33333	-0,3588	3,0254

Based on the reliability test o all questions, Table of the result is shown in Table 5. The result accepts all questions except X3 because of the corrected item-total Correlation of more than 0,3. The answer of X3 can not take as a reliable question or statement. In general, participants agreed to use SCADEF, which consists of its methodology and meta-model artefacts used in Smart City cases. However, the research can continue to improve SCADEF to increase the acceptance as a framework for developing Smart City Architecture more effective and efficient also different from other Enterprise Architecture Frameworks. SCADM is easy to understand and has Four stages: Initiation, Strategy, and Goal; Smart City Modeling; Smart City Design; and Evaluation. The first stage is to identify the scope of the project. Smart City Modeling consists of 3 phases: Smart City Identification, Data Architecture, and Gap Analysis & Improvement. Smart City Design consists of 2 phases: Service Architecture and Information Technology Architecture. The last stage is the evaluation to improve Smart City Architecture as a cycle for continuous improvement and living architecture.

TABLE V
RELIABILITY TEST RESULTS

Item-Total Statistics				
	Scale Mean Item Delete	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
X1	40.1250	13.592	0.588	0.861
X2	40.2083	12.694	0.804	0.848
X3	40.5000	14.957	0.179	0.886
X4	40.1667	13.623	0.620	0.860
X5	40.2083	14.346	0.445	0.869
X6	40.0417	12.998	0.850	0.848
X7	40.0417	12.824	0.744	0.852
X8	40.3333	14.667	0.381	0.871
X9	40.1667	13.188	0.754	0.852
X10	40.2917	15.085	0.303	0.874
X11	40.2917	13.607	0.653	0.858
X12	40.3333	15.188	0.340	0.872
X13	40.2917	14.911	0.368	0.872
X14	40.3333	14.058	0.454	0.869

IV. CONCLUSION

The research has developed SCADEF as Enterprise Architecture Framework to develop Smart City Architecture Framework. SCADEF as Enterprise Architecture Framework includes the methodology, meta-model artifact, and guidelines by implementing SCADEF on the study case. SCADEF has been successfully implemented in the study case to evaluate the SCADEF itself. The comprehensive test has been conducted and measured. SCADEF can be accepted as a recommendation framework for developing Smart City Framework.

ACKNOWLEDGMENT

The authors are grateful to the team involved in this research. The highest appreciation was also addressed to our supervisors. We are obliged to the Education Office and the Bandung City Health Office.

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