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4D Open Spatial Information Infrastructure

Participatory Urban Plan Monitoring in Indonesian Cities

Agung Indrajit

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Agung INDRAJIT

Master of Science in Earth Oriented Space Science and Technology
Technical University of Munich, Germany

born in Jakarta, Indonesia

This dissertation has been approved by the promotors:

Prof.dr.ir. P.J.M. van Oosterom
Dr.ir. B. van Loenen

Composition of the doctoral committee:

Rector Magnificus	chairman
Prof.dr.ir. P.J.M. van Oosterom	Delft University of Technology, promotor
Dr.ir. Bastiaan van Loenen	Delft University of Technology, copromotor

Independent members:

Prof.Dr.ir. C.H.J. Lemmen	The University of Twente, the Netherlands
Prof.Dr. Stan Geertman	The Utrecht University, the Netherlands
Prof.Dr.ir. Ketut Wikantika, M.Sc	Institute Technology of Bandung, Indonesia.
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Prof.Dr.ir. M.F.W.H.A. Janssen	Delft University of Technology, the Netherlands
Prof.Dr.ir. arch. I.S. Sevil Sariyildiz	Delft University of Technology, the Netherlands

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RISETPro
RESEARCH & INNOVATION IN SCIENCE & TECHNOLOGY PROJECT

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to all city dwellers
untuk penduduk kota

Contents

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Summary

An urban plan contains a set of agreements from all stakeholders that may directly impact livelihood. However, many cities show a '*plan and forget*' behavior by not monitoring and evaluating their urban plans. While local citizens are often excluded after the urban plan is enacted. Gibbs (2016) warned of the risk of this behavior by saying, "*local communities are given the impression that the risk is being managed, when in fact it is not*." Therefore, as the affected party, local citizens should be included in the development of the plan and the monitoring, evaluating, and reporting of urban plan implementation. However, in reality, a collaboration between authorities and local citizens in monitoring land development is rare. In some cases, cities do not share urban plans with society. This situation motivates this research by developing a framework to make urban plans interoperable and accessible to the broader community by determining four particular objectives: (i) to identify what type and specification of spatial data are required to support participatory monitoring of the implementation of the urban plan; (ii) to design information interoperability of land-use plans for participatory urban plan monitoring; (iii) to construct spatial data governance that allows two-way information flows between stakeholders in participatory urban plan monitoring; and (iv) to develop a prototype for PUPM that enables two-way information flows and multidimensional spatial representation to support participatory urban plan monitoring. This study was built upon the four functions of land management: land tenure, land valuation, land-use planning, and land development. Information interoperability is essential for allowing interaction between these functions, particularly in PUPM. This study supports the revision of the ISO 19152 on the *Land Administration Domain Model* (LADM) by developing Spatial Plan Information Package (SP Information Package) for accommodating information from land-use planning and land development planning. In recent years, cities have adopted the digital twin concept to represent physical urban objects by exploiting 3D spatial information for improving the spatial thinking of all stakeholders. A common interest of urban planners in using an updated 3D spatial information for Rights, Restrictions, and Responsibilities (RRRs) was depicted for further analysis. Therefore, this study proposes the digital triplets concept for representing the legal situation of the land in four-dimensional representation (3D geometry with temporal aspect managed as an attribute). This thesis presents the development of a prototype using 4D spatial representation for supporting PUPM. The prototype enables two-way information flows between urban planners and citizens to enable the co-production of urban information. This study also proposes user-centered and data governance aspects in a holistic approach to implementing the proposed standard and technology, particularly for sharing RRRs with all stakeholders through an Open Spatial Information Infrastructure. The result of this study is implemented with actual urban plan data in the two biggest Indonesian cities: Jakarta and Bandung City. A usability test was conducted to assess the implementation of participatory urban plan monitoring using RRRs. The result shows that our approach can accommodate RRRs from the spatial planning process, providing a complete overview of the legal situation

of the land or urban space to all stakeholders to monitor the implementation of urban plans to support the Sustainable Development Goals: *'plan and progress'*.

Samenvatting

Een ruimtelijk plan bevat een reeks afspraken van alle belanghebbenden die rechtstreeks van invloed zijn op de leefbaarheid van een omgeving. In veel steden geldt in de praktijk echter '*plan and forget*', doordat de feitelijke ontwikkelingen niet voldoende worden gemonitord. De lokale burgers worden vaak buitengesloten nadat het ruimtelijk plan is vastgesteld. Gibbs (2016) waarschuwde voor het risico van dit gedrag: '*local communities are given the impression that the risk is being managed, when in fact it is not*' (lokale gemeenschappen wordt de indruk gegeven dat de risico's onder controle zijn, terwijl dit in feite niet het geval is). Daarom moeten de lokale burgers worden betrokken bij de monitoring, evaluatie en rapportage van de uitvoering van ruimtelijke plannen. In werkelijkheid is samenwerking tussen autoriteiten en burgers bij het monitoren van ruimtelijke ontwikkelingen echter zeldzaam. In sommige gevallen delen steden zelfs de ruimtelijke plannen niet met de samenleving. Deze situatie motiveert dit promotieonderzoek om ruimtelijke plannen uitwisselbaar en toegankelijk te maken voor de bredere gemeenschap via PUPM ('*Participatory Urban Plan Monitoring*', participatieve monitoring van de uitvoering van het ruimtelijk plan) op basis van: (i) bepalen welk type en specificatie van ruimtelijke gegevens nodig zijn voor PUPM; (ii) het ontwerpen van informatie-interoperabiliteit van plannen voor PUPM; (iii) ruimtelijk gegevensbeheer op te zetten welke informatiestromen in twee richtingen tussen belanghebbenden bij PUPM mogelijk maakt; en (iv) het ontwikkelen van een prototype voor PUPM gebaseerd op informatiestromen in twee richtingen en multidimensionale ruimtelijke representatie ter ondersteuning van participatieve plan monitoring. In dit onderzoek zijn alle vier de functies van land administratie van belang: eigendomsregistratie, waardebepaling, ruimtelijke ordening en ruimtelijke ontwikkeling. Interoperabiliteit van informatie is essentieel om interactie tussen deze functies mogelijk te maken, zoals van groot belang in PUPM. Dit promotieonderzoek draagt bij aan de herziening van de ISO 19152 standaard over het *Land Administration Domain Model* (LADM) door de ontwikkeling van het '*Spatial Plan Information Package*' (SP Information Package) voor het representeren van ruimtelijke plannen. In de afgelopen jaren hebben steden het concept van de *'Digitale Twin'* opgepakt om fysieke objecten weer te geven via een 3D-representatie om zo beter het ruimtelijk denken van alle belanghebbenden te ondersteunen. De rechten, beperkingen en verantwoordelijkheden (*'Rights, Restrictions, and Responsibilities'*, RRR's) rond ruimtelijke eenheden moeten ook via een 3D-representatie worden weergegeven voor verdere analyse. Daarom stelt dit promotieonderzoek het concept van *'Digital Triplets'* voor om zo de juridische situatie van de omgeving in een 4D weer te geven (3D-geometrie met temporeel attribuut). Dit proefschrift presenteert de ontwikkeling van een prototype met behulp van deze 4D ruimtelijke representatie ter ondersteuning van PUPM. Het prototype maakt informatiestromen in twee richtingen mogelijk tussen planologen en burgers om zo de coproductie van stedelijke informatie mogelijk te maken. Dit promotieonderzoek stelt een gebruikersgerichte aanpak en gegevensbeheeraspecten voor in een holistische benadering bij de implementatie van de voorgestelde standaard en technologie, met name voor het delen van informatie met alle belanghebbenden via het Open SII (*'Spatial Information Infrastructure'*,

ruimtelijke informatie infrastructuur). Het resultaat is getest met echte ruimtelijke plannen van de twee grootste Indonesische steden: Jakarta en Bandung. Er is een bruikbaarheidstest uitgevoerd om de daadwerkelijke implementatie van PUPM te beoordelen. Het resultaat toont aan dat onze aanpak de juridische ruimten (RRR's) uit het ruimtelijke planningsproces kan accommoderen, en zo een compleet overzicht te geven van de juridische situatie van de stedelijke ruimte aan alle belanghebbenden. Door deze monitoring van de ruimtelijke plannen wordt er bijgedragen aan het behalen van de 'Sustainable Development Goals' (Duurzame Ontwikkelingsdoelen'): *'plan and progress'*.

List of acronyms

2D	:	Two Dimensional
3D	:	Three Dimensional
4D	:	Four Dimensional
ADR	:	Action Design Research
Bappenas	:	*Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency)
BIG	:	*Badan Informasi Geospasial* (Geospatial Information Agency)
BIM		Building Information Model
BPN	:	*Badan Pertanahan Nasional* (National Land Agency)
CEN	:	European Committee for Standardization
CityGML	:	City Geography Markup Language
CKAN		Comprehensive Knowledge Archive Network
CLAP		City Level Action Plans
COM	:	Common Operational Map
CSW	:	Catalogue Service for the Web
DNN	:	Distributed Network Node
DR	:	Design Research
DRC	:	Disaster Recovery Center
DTM	:	Digital Terrain Model
EODB		Ease Of Doing Business
EU	:	European Union
FAIR	:	Findable, Accessible, Interoperable, and Reusable
FAO	:	Food and Agriculture Organization
FIG	:	International Federation of Surveyors
f-VGI		facilitated Volunteered Geospatial Information
GDP	:	Gross Domestic Product
Geo-ICT	:	Geospatial Information Communication and Technology
GISTARU	:	GIS *Tata Ruang* (GIS for Spatial Planning)
glTF	:	Graphics Library Transmission Format
GOI	:	Government of Indonesia
GML	:	Geography Markup Language
GSJ	:	*Garis Sempadan Jalan* (Road Demarcation Line)
GSM	:	*Garis Sempadan Muka* (Building Front Demarcation Line)
GSS	:	*Garis Sempadan Sisi* (Building Side Demarcation Line)
ICA	:	International Cartographic Association
IGIF	:	Integrated Geospatial Information Framework
IoT	:	Internet of Things
ISO	:	International Organization for Standardization
KKP	:	*Komputerisasi Kantor Pertanahan* (Computerized Land Office)
KDB	:	*Koefisien Dasar Banginan* (Building Base Coefficient)
KDH	:	*Koefisien Dasar Hijau* (Green Base Coefficient)

KLB	:	*Koefisien Lantai Banginan* (Building Floor Coefficient)
KTB	:	*Koefisien Tinggi Banginan* (Building Height Coefficient)
LA	:	*Land Administration*
LADM	:	Land Administration Domain Model
LG	:	Local Government
LOD	:	Level of Detail
LSK	:	Local Spatial Knowledge
PID	:	Public Information Disclosure
PPGIS	:	Public Participatory in Geographic Information System
PUPM	:	Participatory Urban Plan Monitoring
NGO	:	Non-Government Organizations
NNC	:	Network Node Connector
NRC	:	National Research Council
ODI	:	One Data Indonesia
ODP	:	Open Distributed Processing
OGC	:	Open Geospatial Consortium
OECD	:	Organization for Economic Co-operation and Development
OMP	:	One Map Policy
OSS	:	Online Single Submission
PUPM	:	Participatory Urban Plan Monitoring
RDTR	:	*Rencana Detail Tata Ruang* (Urban Plan)
RTRW	:	*Rencana Tata Ruang Wilayah* (Spatial Planning)
RM-ODP	:	Reference Model-Open Distributed Processing
RRRs	:	Rights, Restrictions, and Responsibilities
SDG	:	Sustainable Development Goal
SDI	:	Spatial Data Infrastructure
SII	:	Spatial information Infrastructure
SP	:	Spatial Planning
SWE	:	Sensor Web Enablement
TPZ	:	*Teknik Pengaturan Zonasi* (Zoning Arrangement Technique)
UPI	:	Urban Planning Information
UN	:	United Nations
UN-ECE	:	United Nations Economic Commission for Europe
UN-GGIM	:	United Nations of Global Geospatial Information Management
VGI	:	Volunteered Geospatial Information
WFS	:	Web Feature Service
WMS		Web Map Service

1
Introduction

1.1 Motivation

Facilitating urban plans for local citizens to monitor their neighborhood is essential to maintain and improve their livelihood toward sustainable development. Urban plans are used as a reference in making land management effective, including land-use control and land development. However, many cities are lacking or not sharing urban plans. Cities should disseminate urban plans in reusable format to represent the Rights, Restrictions, and responsibility (RRRs) of a land parcel or urban space for supporting local citizens to monitor the implementation of urban plans. This study should support moving from the 'plan and forget' toward the 'plan and progress' behavior. This situation motivated this thesis research to make urban plans interoperable and shared with local citizens to perform Participatory Urban Plan Monitoring (PUPM).

1.2 Background

The UN member countries ratified the Agenda for sustainable development or Sustainable Development Goals (SDGs) in 2015 (United Nations 2015). Mr. Ban-Ki-Moon, the former Secretary-General of the United Nations (UN), acknowledged the role of cities in SDGs by stating, "*Our struggle for global sustainability will be won or lost in cities*" (UN Secretary-General 2012). Logically, ensuring SDGs' success depends on how indicators are successfully localized and integrated into urban plans and monitoring their implementation over time. Today's cities are the engine of economic growth and contribute to most of the world's Gross Domestic Product (GDP) (Acuto et al. 2018, Ringenson et al. 2017, and World Bank 2020). Consequently, the urban area is experiencing more pressure from urbanizations and investments. Cities must have the capability to provide up-to-date spatial information for the localization of SDGs, including developing urban plans, monitoring and evaluating interventions, and urban development (UCLG 2017).

The smartness of a city shall be characterized by spatial enablements and its ability to facilitate the society to access and contribute spatial data (Roche 2014, Tomor et al. 2019, and Geertman et al. 2020). A smart city must encourage its citizens to participate in urban management (Hernández-Muñoz et al. 2011). For this, cities must establish reliable data sharing mechanisms, including usable toolsets and supporting regulations and funding for the data ecosystem. The availability and accessibility of spatial information are embedded in urban intelligence, such as measuring and mining urban data, correlating ideas and facts, coordinating stakeholders, and harnessing citizens' participation (Batty 2012). A decade ago, the spatial enablement concept was proposed to understand the importance of location, place, and maps for society. This concept put spatial information at the center for supporting activities and decision-making, particularly in land management activities. The spatially enabled city and society rely on Spatial information Infrastructure (SII), also known as Spatial Data Infrastructure (SDI), for facilitating land information sharing between economic actors (Steudler & Rajabifard 2012 and Roche & Rajabifard 2012) and for supporting the modernization of the city's Land Administration System (LAS) (Enemark 2005).

Local governments and communities develop building and other physical interventions in the urban area (or space) using public and private investments. This modification also changes Rights, Restrictions, and Responsibilities (RRRs)on the particular land parcel or urban space (Van Oosterom et al. 2009). These changes should be well-reported, standardized, managed, and analyzed because of their importance and the impacts that may follow. At the same time, cities are facing difficulties in providing and updating maps to represent urban dynamics. There is an urgent need for a city to provide a mirror image representing both physical and legal objects (RRRs) over time. However, "*plan and forget*" behavior often happened in many cities worldwide (Gibbs 2016), for example, by not monitoring and evaluating the implementation of urban plans. Suppose urban plan left unmonitored (or worse, neglected). In that case, it will stimulate urban sprawls (Vermeiren et al. 2012), infrastructure strain and pressure on essential urban services, and over-burdened logistic systems (Güneralp & Seto 2008). Local citizens possess local spatial knowledge that is valuable for the whole urban planning process. Local citizens should be involved and allowed to access and contribute relevant spatial information in the urban plan monitoring as affected parties. The following sub-sections present three aspects that are influencing participatory urban plan monitoring: interoperability of land information, data ecosystem that allows open spatial data sharing, and local situations. There are three issues in Participatory Urban Plan Monitoring (PUPM) covered in this study: information interoperability, open spatial data sharing, and implementation based on local situations.

1.2.1 Information interoperability in land management

In the late 1990s, the International Federation of Surveyors (FIG) proposed the "*Cadastre 2014 Vision*" to kick-start the modernization of the LAS around the world (Kaufmann & Steudler 1998). This vision encourages countries to accelerate their efforts to provide a complete overview of land (and space) and its legal dimensions. In 2014, FIG strengthened this vision to "*Cadastre 2014 and Beyond*", further stressing the provision of a complete legal situation of land (and space), integration between legal documents and its spatial representation, and standardized use data model for land management (Steudler 2014). This updated vision indicates integrating a modernized LAS with Spatial Information Infrastructure (SII) to safeguard successful land management and improve outreach to relevant stakeholders and communities, particularly landowners, property owners, and economic actors.

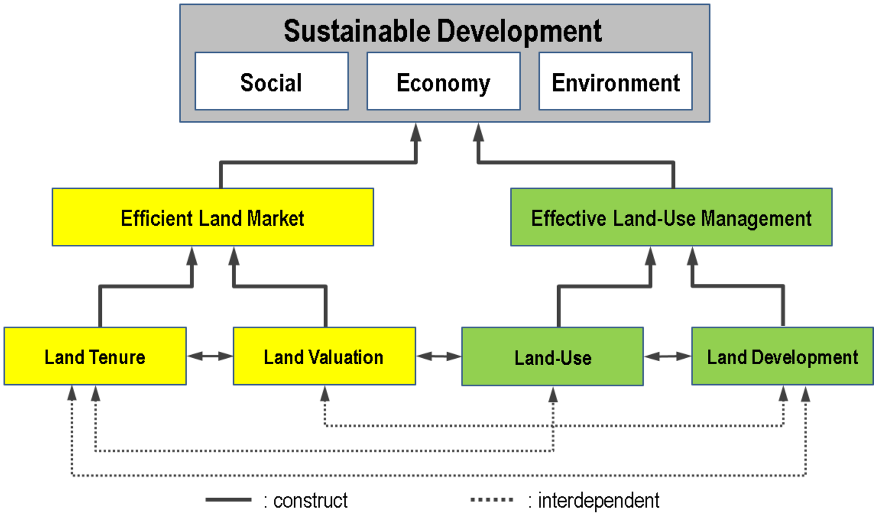

Figure 1-1. A global perspective of land administration land management paradigm towards Sustainable Development Adapted from Enemark (2005).

In 2005, Enemark (2005) proposed the "*Land Management Paradigm*" for achieving sustainable development. This paradigm identifies four functions of land management: land tenure (and cadastre), land value, land use, and land development (Figure 1-1). Land tenure manages data about rights (public and private laws) on land or properties, while land valuation focuses on fiscal information (land price, transaction price, and mass valuation). Land-use and land development planning create zoning regulations that prescribe characteristics (privileges, prohibition, and obligations) on a specific area of land or space. Interoperability has been widely identified as one of the main issues in the spatial data sharing process, including semantic (Harvey et al. 1999) and technical interoperability (Hernández-Muñoz et al. 2011). Geospatial and cadastre communities continuously promote standardization for land information to avoid inefficiencies and disputes between economic actors (i.e., local governments, landowners, and investors). There is a diversity of LASs between countries (and sometimes within countries) due to differences in laws, surveying practices, Geospatial Information Communication and Technology (Geo-ICT) capabilities, and social aspects (Lemmen 2012). Cities utilize land registration to secure land and property rights. Simultaneously, authorities at different jurisdictions conduct land-use planning in zoning regulations, imposing restrictions on land parcels and responsibilities to landowners. Therefore, information interoperability on land registration and land-use plans are vital in land management to construct complete RRRs information.

In many countries, data management of land registration and land-use planning are managed by different government entities (federated environment) (Enemark 2009). For example, the responsibility for land tenure and land valuation is in national land agencies, while local governments are responsible for organizing land-use planning and land development planning. Therefore, standardization plays a critical role in enabling information interoperability in four functions of land management. Further, it will help authorities and communities to monitor the implementation of the land-use plan. The International Organization for Standardization (ISO) published ISO 19152:2012 about the Land Administration Domain Model (LADM) to provide a shared conceptual information model for countries in establishing or improving LAS and to better representing the relationship between people and land (and space) (Lemmen et al. 2013). The LADM is capable of documenting RRRs and geometrical components in 3D dimensions (Van Oosterom 2013). This research regards a 4D representation as 3D spatial information with temporal information managed to represent (planned) changes (3D+time). This research covers standardization and construction of 3D RRRs from land-use plans for monitoring the implementation of the land-use plan. The needs for data sharing mechanisms and multiparty involvements working collaboratively, particularly economic actors and communities in the land management paradigm, are inevitable, putting information interoperability as the critical criteria for a modern LAS of a city. Indonesia’s legal framework allows academia, business, communities to access spatial information via SII, including land information Access to land information will make the society smarter and spatially enabled. Moreover, Spatial Planning Act mandates local governments to facilitate local citizens and non-governmental organizations to monitor and evaluate urban plan implementation.

1.2.2 Open spatial data sharing at the city level

Urban plans consist of information about restrictions and responsibilities. This information is essential to construct a complete legal object of land and space if combined with information about rights from land tenure activities. However, cities focus on the physical object and developing digital twins containing 3D city models with (near) real-time monitoring systems (Batty 2018). An urban plan monitoring needs up-to-date information about the physical and legal objects of a city. A comparison of a city's digital twin with its legal object is essential in deciding corrective responses from authorities and communities, mainly for ensuring urban planning success. Therefore, access to information on four functions of land management is crucial for successful urban plan monitoring. The UN and FIG have stated the SII as the backbone of facilitating access to land information (Scott & Rajabifard 2017 and Steudler 2014). However, the notion of a single producer of spatial information is no longer valid nowadays. Many authorities fail to provide the high cost of conventional mapping (Kelmelis et al. 2003 and Arnold et al. 2019). On the contrary, the advancements of Geo-ICT in the past decade are enabling citizens and non-government institutions to produce and update maps in a faster and cheaper way than conventional mapping. To represent this approach, Michael Goodchild (2007) introduced the term "*Citizens as sensors*" as an alternative source of Local Spatial Knowledge (LSK) with lesser quality but still useful for urban management. Local knowledge of their neighborhood contributed by local citizens offers unique information that is not comparable to the experts' knowledge. Citizens' capability to monitor their livelihood using spatial representation is improving since the last decade (Arsanjani et al. 2015, Crooks et al. 2015, Kanhere 2013, and Herfort et al. 2019).

1.2.3 Participatory urban plan monitoring in Indonesia

The 1945 Indonesian Constitution recognizes land and space as public goods for its usage sought the people's maximum welfare while respecting ownership rights on land or space. The legal system in Indonesia mandates the government and communities to manage and protect land, space, and natural resources. Basic Agrarian Act and Spatial Planning Act acknowledge land and space as public property in which decision-making requires *musyawarah* (consensus) from involving parties, including communities, without any threats or pressures. From the constitutional perspective, land policies shall be directed toward optimal land and space uses for preservation, productivity, and quality of life. The most critical stage in the spatial planning process is the supervision and control of land (and space) utilizations and developments to ensure urban plan implementation.

Sloan (2014) reported that problems in the land-use planning process might be rooted in the absence of quality maps and a lack of transparency among authorities. Indonesian cities are experiencing inconsistencies in land or space use from the spatial plan (Jazuli 2017 & Junef 2017). It is common to find inconsistencies between location license/permit, spatial plan, and actual land or space usage. It is becoming a chronic and widespread problem across Indonesia (Mulyani & Jepson, 2017). Monitoring and evaluating land use should be based on permits given by authorities as a tool to regulate people's behavior (Djalmiati 2007). In Indonesia, the Spatial Planning Act mandates authorities to cancel land or space utilization permits that violate the spatial (urban) plan; permits issued or obtained through improper ways are void. Authorities are prohibited from issuing a permit that is not following the spatial plan. Indonesia's Spatial Planning

Act recognizes citizens' involvement as essential stakeholders in all phases of spatial planning (development, utilization of land and space, and monitoring and controlling land or space). Citizens' participation in spatial planning, particularly at the city level, aims to improve safety, livability, convenience, and productivity. Local governments have responsibilities in fostering and facilitating citizens' roles in spatial planning. The Government of Indonesia (GOI) enacted Government Regulation No. 68/2010 to secure community rights and responsibilities, encourage citizens' contributions, realize transparency, effectiveness, accountability, quality of the spatial plan, improve public services and policy-making through spatial planning. Local governments are developing the GISTARU (abbreviation for GIS for Spatial Planning) application using the Geo-ICT to disseminate maps and documents from the spatial planning process to all stakeholders, particularly local citizens. Most GISTARU applications were developed using web-based GIS, where local governments, as spatial data producers, introduce only a limited type of data and roles for citizens. The GISTARU is limited to provide 2D spatial plans, disconnected from LAS, and not yet to enable the full potential of LSK in monitoring implementation of the urban plan nor to facilitate the citizens in contributing spatial data into the system (Rahmawati & Sulchan, 2018).

1.3 Research question

The main focus of this research is to develop mechanisms and tools for allowing all stakeholders to exchange multidimensional spatial information for monitoring the implementation of urban plans. Four aspects are covered in this research: type of spatial information that should be included in the system, specification of urban plans and its multidimensional representation, data governance for open spatial data sharing, and development and testing of a 3D web prototype for facilitating participatory urban plan monitoring. This research is focused on answering the following question: **"*How to design and implement The Open Spatial Information Infrastructure for 4D Participatory Urban Plan Monitoring?*"**

The accompanying research sub-questions that are related to this research and will also be answered are:

i. **What type of spatial information is necessary for supporting participatory urban plan monitoring in Indonesian cities?**

   This sub-question assesses users' requirements (planners, data custodians, and potential contributors) for spatial information needed for contributing data into participatory urban plan monitoring and evaluates gaps between producer-based and user-centered spatial information specifications for urban plan monitoring and gaps on data producer's roles and responsibilities in creating participatory urban plan map.

ii. **What is the preferred specification of a land-use (urban) plan may address participatory urban plan monitoring?**
This sub-question identifies a possible spatial representation of land-use (spatial) plans for participatory monitoring of the urban plan's implementation. The study will assess how standardization can ensure information interoperability of spatial plans and what should be performed to develop a land-use (urban) plan data model with appropriate spatial representation.

iii. **What are the preferred criteria of open spatial data sharing to support participatory urban plan monitoring?**
This sub-question assesses what criteria of the Open SII may support participatory urban plan monitoring. The examination of criteria includes organizational aspects by integrating open data and open participation principles into spatial information infrastructures to allow active contribution from government, private sectors, and citizens to monitor the urban plan's implementation.

iv. **How to design a system that allows for spatial data sharing in participatory urban plan monitoring?**
This sub-question will incorporate a study on implementing a two-way information flow on the Open SII to support participatory urban plan monitoring. The development of the prototype examines how a standardized urban and 3D and time representation of urban plans may improve participatory urban plan monitoring. The 3D web technology built on the Open SII ensures optimal outreach to all stakeholders, particularly local citizens. This sub-question will be answered by developing a prototype and performing usability testing of two-way information sharing tools to support participatory urban plan monitoring.

1.4 Research methodology

Stakeholders require spatial information that representing physical and legal objects to monitor the implementation of urban plans. During the research, Indonesian cities, including Jakarta and Bandung, use urban plans to reference land management activities. Simultaneously, the central government maintains a land registry through *Badan Pertanahan Nasional* (BPN) (National Land Agency). In the Indonesian regulatory framework, local governments are instructed to facilitate local citizens to monitor and supervise the implementation of the urban plan, including providing information and communication systems. On the other hand, Indonesian cities and BPN are already participating in the National SII for spatial data sharing among government institutions. Although regulation permits local citizens to access and contribute spatial information through SII, there is still a lack of facilitation to perform their rights. Consequently, many types of spatial information needed are not accessible and shared in reusable format for local citizens to monitor the implementation of urban plans. Further, relevant land information is in 2D format, which needs to be assessed their usefulness to be used in Participatory Urban Plan Monitoring (PUPM).

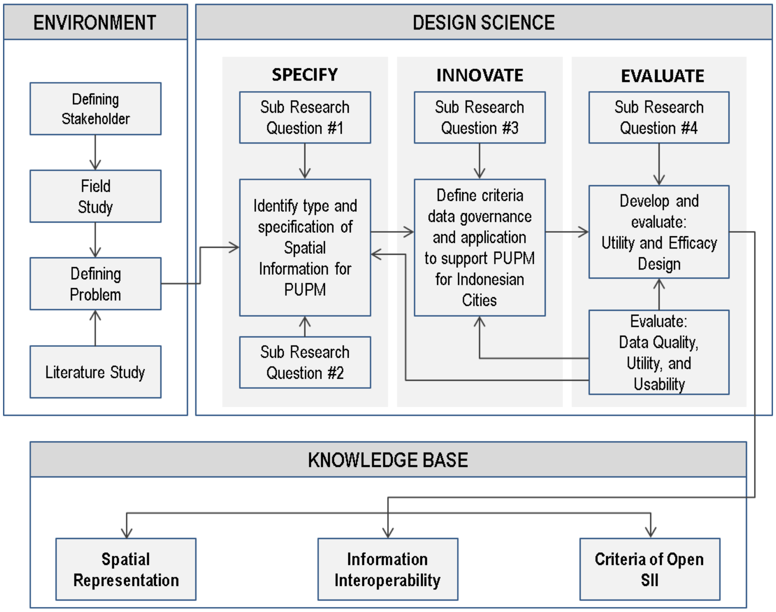

Figure 1-2. Design research for participatory urban plan monitoring

This study implements the Action Design Research (ADR) proposed by Sein et al. (2011). The ADR, a combination of Action Research (AR) and Design Research (DR), is implemented based on its capability to examine the extent to which the intervention is received as intended. This research performs three main parts: specify, innovate, and evaluate. Determination of specification for PUPM is for identification of functional and users' requirements. Innovations proposed in this research are conducted iteratively with evaluation to improve the ongoing process in Indonesia's situation and policies. This study starts with identifying problems on the use of spatial information by stakeholders to monitor urban plans in Indonesian cities using literature studies, surveys, and field studies at national and local levels. A framework to assess which types of spatial information and the specification of spatial plans were developed based on the regulation, function, and users' requirements. In the identification of requirements, we focus on three types of users: (1) data custodians, (2) urban planners, and (3) potential contributors. The effectiveness and efficiency for supporting Participatory Urban Plan Monitoring (PUPM) of types of spatial information needed and specification of urban plans were examined using the ADR approach. Second, this study also considers data governance by developing Open Spatial Information Infrastructure (SII) criteria that can perform a two-way information flow and multidimensional representation to support PUPM while ensuring information interoperability. Criteria of the Open SII are then discussed with stakeholders to develop awareness and consensus. In the last step, this study develops a prototype for PUPM and evaluates how multidimensional representation and two-way information flow can better assist PUPM (Figure 1-2).

1.5 Scope of the research

This research addresses the use of spatial information in participatory urban plan monitoring. Planners develop spatial (urban) plans to contain a consensus from many competing interests. Activities around monitoring and evaluating the implementation of an urban plan are crucial but not yet sufficiently realized to maintain the conformity of land (or space) utilization and development with the spatial function specified in the urban plan.

a) Information interoperability is required in managing information in land management functions. A standardized data model helps integrate land-use (urban) plans with other closely related data used in land tenure, land valuation, and land development, including participatory urban plan monitoring.
b) Urban plan monitoring may include detection of compliance, violation, infringements, or performance of the implementation of the urban plan. Detection of objects and activities on a land parcel or space located under, on, or above urban areas is considered subsets of urban plan monitoring. Although this research acknowledges local citizens as a sensor but still considers authorities as a validator of spatial information. Authorities then may take action based on validated spatial information contributed by local citizens.
c) Types of urban plan monitoring may differ in each country. In Indonesia, Spatial Planning Regulation distinguishes two types of monitoring and evaluation in urban planning: technical and specific monitoring. Technical monitoring covers the whole urban planning process periodically, while specific monitoring concerns specific problems as needed. This research focuses on technical monitoring of urban planning for sensing, documenting, and reporting changes in the urban environment concerning the urban plan.
d) Participatory urban plan monitoring attempts to accommodate broader stakeholders, particularly residents most affected by neighborhood activities. In Indonesia, the legal framework allows local citizens to access public information and mandates local governments to enable citizens to contribute information.
e) The Open SII is defined as facilitating spatial information sharing that enables two-ways *geocollaboration* by all stakeholders. Open data principles are used in constructing

Open SII, allowing anyone to access, use, modify, and share spatial information for any purposes ranging from low resolution to high-value, high-resolution, or multidimensional datasets). The development of prototype and usability testing to evaluate technological interventions is evaluated to ensure functional improvement on participatory urban plan monitoring.

This research does not cover the focus on several other aspects of 4D spatial information and participatory approach on monitoring and evaluating the implementation of the urban plan. Aspects that are not included in this research as follow:

a) Deep integration of 3D geometrical data with time (4D topology).
b) The 4D topology (x,y,z,t) is often discussed deep integration of geometry and time topic to manage the relationship between primitive features (points, line, and surface). This type of integration is mainly covered in the computational geometry and computer science domains. This research manages the temporal aspect (time) as an attribute of a 3D object.
c) Measuring of quality of spatial information and used in participatory urban plan monitoring.
d) The quality of spatial information is part of surveying and geodetic engineering, while the valuation of information requires socio-economic aspects expertise. This research expects validators to follow ISO 19157: 2013 on Data Quality for quality measurement.
e) Measuring the performance of urban planning is not discussed in this dissertation due to the local situation.
f) Indonesian legal framework specifies a conformance approach for monitoring and evaluating the implementation of the urban plan. Designing an urban plan and monitoring its performance are mainly discussed as the core topic in urban planning studies.

1.6 Outline of the dissertation

This dissertation is arranged in four parts (Figure 1-3): 1. Background, 2. Modelling PUPM, 3. Case studies, and 4. Conclusion. The first part contains Chapter 1 and Chapter 2. The first chapter presents background information on the research and introduces the research questions. Chapter 2 addresses concepts of participatory urban plan monitoring in Indonesia. The second part (Chapters 3, 4, and 5) focuses on developing a framework for selecting relevant spatial information and designing a conceptual data model for information interoperability of a 4D urban plan for PUPM. Chapter 5 presents the development of criteria for the Open SII that can perform a two-way information flow to support PUPM.

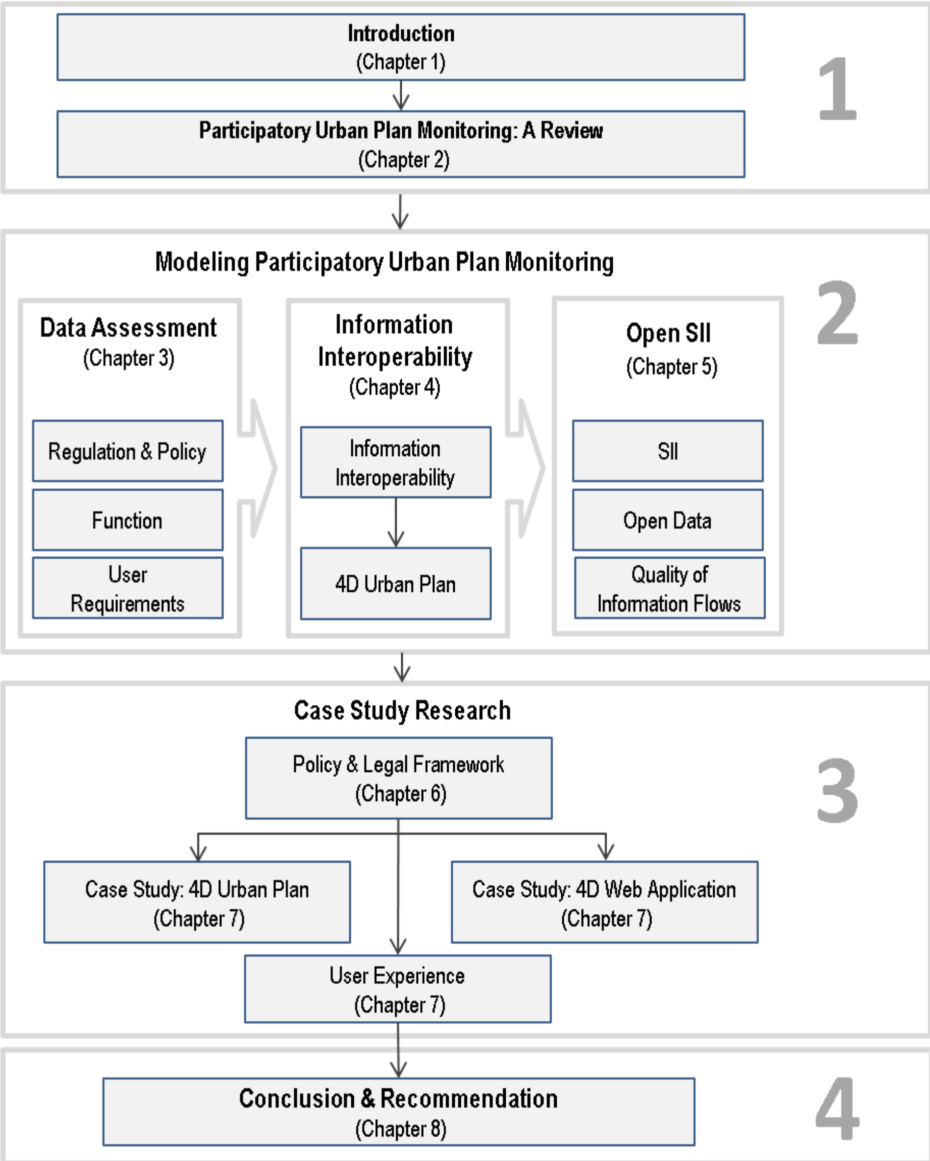

Figure 1-3. Dissertation structure

The third part (Chapters 6, 7) contains the implementation of the selection framework, a conceptual data model for urban plans, and the Open SII criteria at the two biggest Indonesian cities (Jakarta and Bandung). The initial usability testing with actual data is addressed in the last part to assess the effectiveness and efficiency of the prototype of PUPM. The last part (Chapter 9) contains the main conclusions by answering the research questions and providing future research recommendations.

1.7 List of publications

Published Scientific Journal articles:

1. **Indrajit, A.,** Van Loenen, B., & Van Oosterom, P. (2019). Assessing Spatial Information Themes in the Spatial Information Infrastructure for Participatory Urban Planning Monitoring: Indonesian Cities. *ISPRS International Journal of Geo-Information*, 8(7), 305.

2. **Indrajit, A.,** van Loenen, B., Ploeger, H., & van Oosterom, P. (2020). Developing a spatial plan information package in ISO 19152 land administration domain model. *Land-use Policy*, 98 (104111).

3. **Indrajit, A.,** Van Loenen, B., Suprajaka, Eresta Jaya, V., Ploeger, H., Lemmen, C. & Van Oosterom, P. (2021). Implementation of the new spatial planning information package within an LADM country profile: Making land information improves ease of doing business in Indonesian cities. *Land-use Policy*, 105 (105338).

Book Chapter:

1. **Indrajit, A. (2018).** One Data Indonesia to Support the Implementation of Open Data in Indonesia. In Open Data Exposed (pp. 247-267). TMC Asser Press, The Hague.

Conference proceedings:

1. **Indrajit, A.,** van Loenen, B., & van Oosterom, P. (2017). Multi-Domain Master Spatial Information Management for Open SDI in Indonesian Smart Cities. *In AGILE 2017: Proceedings of the 20th Association of Geographic Information Laboratories for Europe (AGILE) Conference on Geographic Information Science*
2. **Indrajit, A**., Ploeger, H., van Loenen, B., & van Oosterom, P. J. M. (2018). Designing Open Spatial Information Infrastructure to Support 3D Urban Planning in Jakarta Smart City. *In Proceedings of the 6th International FIG 3D Cadastre Workshop, Delft, The Netherlands* (pp. 2-4) (**The Best Paper Award** at the 6th International FIG Workshop on 3D Cadastres, and the 3rd International Conference on Smart Data and Smart Cities).
3. **Indrajit, A.**, van Loenen, B., & van Oosterom, P. (2018). Prospect of Open SDI in Developing Countries Case Study: Indonesia. *In AGILE 2018: Proceedings of the*

21st Association of Geographic Information Laboratories for Europe (AGILE) Conference on Geographic Information Science.

4. **Indrajit, A.,** Eresta Jaya, V., van Loenen, B., Snaidman, A., Ploeger, H. D., & van Oosterom, P. J. M. (2019). Implementation of Spatial Planning Package for Construction of an LADM Country Profile: Reducing Asymmetric Access to Information of RRRs in Indonesia. *In Proceedings of the 8th Land Administration Domain Model Workshop (LADM 2019). FIG.*
5. Van Oosterom, P. J., Kara, A., Kalogianni, E., Shnaidman, A., **Indrajit, A.**, Alattas, A., & Lemmen, C. H. J. (2019). Joint ISO/TC211 and OGC Revision of the LADM: Valuation Information, Spatial Planning Information, SDG Land Indicators, Refined Survey Model, Links to BIM, Support of LA Processes, Technical Encodings, and Much More on Their Way!. *In FIG Working Week 2019: Geospatial Information for a Smarter Life and Environmental Resilience*.
6. **Indrajit, A.,** Eresta Jaya, V., Van Loenen, B., Lemmen, C., Van Oosterom, P., Ploeger, H., & Theodore, R. (2020). The Role Of The Revised Land Administration Domain Model And Spatial Data Infrastructure In Improving Ease Of Doing Business In Indonesia. *In 2020 World Bank Conference on Land and Poverty. The World Bank. Washington DC. March 16-20, 2020.*
7. **Indrajit, A.,** Yusa, M. H., Van Oosterom, P, Suwardhi, D., & Van Loenen, B. (2021). Development and Usability Testing of the Participatory Urban Plan Monitoring Prototype For Indonesian Smart Cities based on Digital Triplets. *FIG 2021 Working Week.*

1

2

Participatory Urban Plan Monitoring: An Overview

Successful land use (urban) planning is what every city wants to achieve. Therefore, the implementation of an urban plan should be monitored and evaluated by authorities and the affected parties. This chapter reviews the theories of participatory monitoring as a means of a city and its society to ensure the successful implementation of the urban plan. It begins with the general concept of urban planning to provide the context of spatial information usage in a participatory approach. It consists of four sections and covering urban planning, urban plan monitoring and evaluation, and participatory urban plan monitoring. Section 2.1 present a general overview of urban planning, while Section 2.2 focuses on its monitoring and evaluation. Section 2.3 contains a participatory approach to urban plan monitoring, and the last section presents a summary of the chapter.

2.1 Urban planning

Urban planning is branched off from the architecture discipline (Steinø 2013). However, institutional divide between the educational environments making their theorization divided into separate realms for over a century (Friedman 1987). Urban planning covers the city level or regional level for accommodating political, economic, social, and environmental concerns into a comprehensive plan containing which building and spatial components should be developed in a specific area (Devries et al. 2005). Steinø (2003) conceptualized urban planning as practical means for implementing policies and social change upon space and society at large. According to Friedman (1993), urban planning is future-oriented to seek the connection between knowledge and action. Hall & Tewdwr-Jones (2010) specify that urban planning must consist of, at least, a set of functions of management, monitoring, and controlling urban areas. Food and Agriculture Organization (FAO) (1993) defines land-use planning as a "*systematic assessment of land and water potential, alternatives for land-use, and economic and social conditions in order to select and adopt the best land-use options*." Urban planning integrates policies across various human activities (Biesbroek et al. 2009) and is often used to achieve sustainable development (Allmendinger & Haughton 2010). Thus, an urban plan can represent a holistic view of competing aspects, interests, and different policies proposed and agreed upon by all stakeholders from all levels of jurisdictions and different walks of life.

Countries install a hierarchy for spatial planning (i.e., national, state, province, cities, and local) following administrative jurisdiction levels primarily for decentralizing power and better fulfilling the community's needs with adaptation to socio-cultural preferences and economic opportunities, and capacities of the environment. In this hierarchical mechanism, the lower levels must comply with the upper levels (Pissourios 2014) to maintain degrees of coherence among levels in the spatial planning hierarchy (see the yellow box in Figure 2-1). Pinson (2007) iterates that a land-use (or urban) plan shall contain '*guidelines*' for the whole set of activities to regulate and anticipate the land or urban development. These '*guidelines*' may contain various specifications in Rights, Restrictions, and Responsibilities (RRRs). Urban planning can also be considered as a complex and cyclical process with many cyclical sub-processes (McLoughlin 1969). In reality, it is challenging to document rights consistent with restrictions and responsibilities as countries often arrange their land administration and urban planning in separate systems and different domains (Enemark et al. 2014) (Figure 2-1). For example, land tenure is managed by the national cadastre agency, while local governments are responsible for developing and maintaining urban plans.

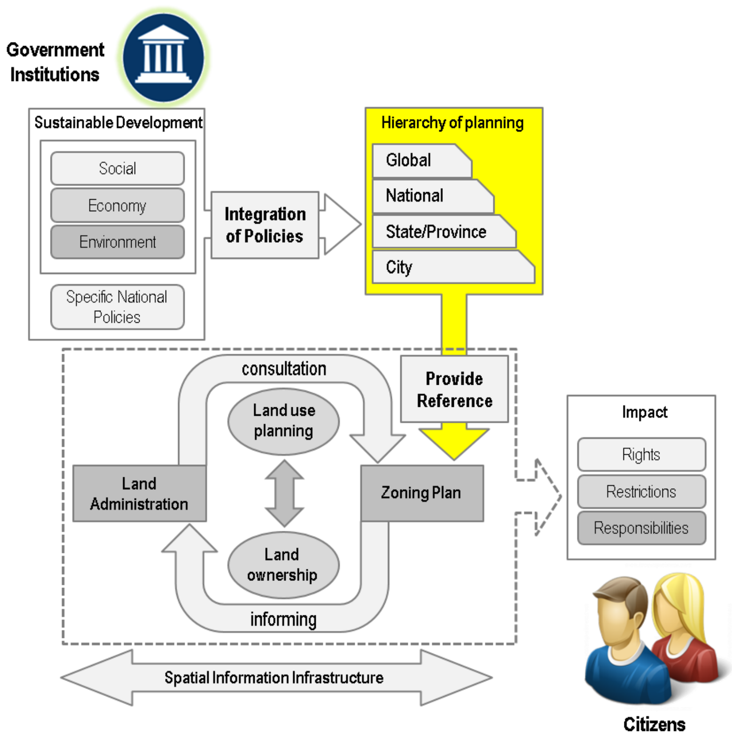

Figure 2-1. Urban plan produces a set of RRRs for each land or space

Van der Molen (2015) prescribes land-use (and urban) planning to consider property rights by consulting and informing landowners before imposing restrictions and responsibilities onto land parcels or urban space to avoid conflicts with existing rights (see Figure 2-1). Thus, countries shall establish an information infrastructure and construct robust data governance models that ensure a linkage between land registration and land-use (or urban) planning.

Table 2-1 "*Six stages of the urban planning process.*"
(Source: McLoughlin 1969)

1. The decision to adopt planning	To start organizing urban planning by bidding all stakeholders' commitment to legal reinforcement to ensure sustainability and collaborative actions. The decision to adopt urban planning begins with identifying the real world (including obstacles and potential problems) and the system's current state before determining each stakeholder's purposes and roles.
2. Formulation of goals and objectives	To identify and determine a set of goals for urban planning to guide the course of action. Identifying objectives often accompanies the formulation of goals and measurement of impact analyses to relate physical planning to collective action and stated in the plan charter. Each goal or target can be adjusted or amended afterward.
3. Study of possible alternatives	To examine possible alternatives by modeling techniques to select the optimal solution. Modeling techniques are used to forecast future conditions in detail for each defined alternative. The examination includes how the system might behave under a variety of influences through time.
4. Compare and evaluate various alternatives	To examine possible alternatives using cost-benefit analysis and public consultation. The model is employed to measure and evaluated the predefined social values and cost-benefit estimation with time-constrained. Each evaluation of alternatives will be examined thoroughly. The chosen alternative will be promoted as an operational course in later stages.
5. Taking actions through the public investment of control over private investment.	To facilitate planners to control the outcomes from an individual of public interventions or limited resources with minimal problems. The model considers that urban planning actions are interdependent with the current condition (i.e., land-ownership and land-use) and works in a continuous flow of change through time. Interventions with direct or indirect actions are documented in the form of RRRs information.
6. Monitoring of the state of the system	To study urban planning and its control mechanism through time. The periodic review may cover the socio-cultural, political, economic, or ecological context in which the plan function. A plan can be under significant review for a longer time or minor review at shorter intervals.

Hall & Tewdwr-Jones (2010, 211) argue that urban planning is a continuous process to improve ways of controlling the urban system with spatial components. McLoughlin (1969) construct six stages of urban planning: the decision to adopt planning, formulation of goals, the study of possible alternatives, compare and evaluate various alternatives with cost-benefit analyses, taking actions through the public investment of control over private investment, and monitoring of the state of the system (see Table 2-1). Urban plans will be used as the reference for issuing permits for land development. The study focuses on the facilitation of local citizens to monitor the urban plan implementation by moving forward from 'plan and forget' practices to 'plan and progress' attitudes.

2.2 Urban plan monitoring and evaluation

Urban planning considers a city dynamic and continuously influenced by internal and external factors (Batty 2009). Since the beginning of the urban planning process, a city should integrate monitoring and evaluation initiatives and implement them. Thus, a city must establish a reliable monitoring system for evaluating the urban area and its surroundings over time. However, '*plan and forget*' behavior can be found in many cities worldwide, and the study on how to facilitate urban plan monitoring is scarce.

2.2.1 Definition of urban plan monitoring

Monitoring is an essential part of the policy-making process and is often illustrated as an interactive sequence of interacting stages. Organization for Economic Co-operation and Development (OECD) (2002) defines monitoring as "*…a continuing function that uses systematic collection of data on specified indicators to provide management and the main stakeholders of an ongoing development intervention with indications of the extent of progress and achievement of objectives…*." In urban planning, Seasons (2002) defines four monitoring elements: policies, programs, processes, and plans. Monitoring is often paired with an evaluation to add insight for decision-makers. There are three primary purposes of monitoring and evaluation: for making judgments (Trochim 2001), for improving programs (Patton 2008), and for gauging the ongoing development (Weiss 1997).

Policy implementation analysis of urban planning can be appraised through monitoring and evaluation by comparing the actual conditions and processes to the normative requirements (Alexander 2002). We can summarize five policy-plan-implementation evaluation criteria from Alexander & Faludi (1989): conformity, rational process, optimally ex-ante, optimally ex-post, and utilization. In urban plan monitoring, the conformity criterion evaluates the implementation of the plan and actual outputs, outcomes, and impacts based on the predefined goals, objectives, and specifications expressed in urban plans. The rational process is similar to the conformity criterion but referring to normative specifications in urban plans with more general conditions (i.e., completeness, consistency, and participation). *Optimally ex-ante* considers whether implementing an urban plan is optimal according to the relationship between objectives and efforts. On the contrary, *optimally ex-post* assess the effects of the urban plan. The last criterion, utilization, evaluates whether the urban plans were used for operational decisions, such as permits or land development. Monitoring and evaluation of urban plans require a proper study on indicator determination. This study implements the conformance criterion. Thus, indicators to be used in this study are the actual output, outcomes, and actual impact. This research considers urban plan monitoring as "*a continuous function that uses systematic collection of urban data on specific indicators to represent the extent of progress and achievement of urban plan objectives.*"

2.2.2 Types of urban planning monitoring

Monitoring functions as an instrument for policy implementation analysis (Alexander 2006). Faludi (1989) classifies policy implementation analysis into two types: performance and conformance. The "*performance*" approach evaluates how each decision in urban planning can accomplish one or more goals via qualitative and quantitative analyses. In this approach, the urban plan is used as a guide rather than the output or outcome. In contrast, the "*conformance*" approach uses an output-based examination for the object of planning (Alexander & Faludi 1989 and Talen 1997). According to Berke et al. (2006), the conformance approach better highlights the parameter of success than the performance approach. Faludi (1989) argues that the conformance approach is more suitable for monitoring and evaluating a plan for its objectivity in measuring urban planning success.

Table 2-2 Typology of urban planning monitoring and evaluation
(Source: Talen 1996)

Types of evaluation	Scopes
evaluation prior to plan implementation	consists of the evaluation of alternative plans and analysis of planning documents.
evaluation of planning practices	studies around planning behavior and impacts of planning and plans.
policy implementation analysis	focuses on assessing the conditions after a plan or policy is enacted, including evaluating the administrative and implementation process.
evaluation of the implementation of plans	consists of two approaches: non-quantitative and quantitative. A quantitative evaluation of the implementation of plans aims to provide rigorous, empirical, and quantitative evidence for planning practices (Healey 1986 and Bryson 1991) and present compliances and deviations in particular area units.

Chapin et al. (2008) also show the conformance approach's ability to capture parcel-based land utilization using spatial information. Talen (1996) develops a planning evaluation typology in four categories applied in urban plan monitoring (see Table 2-2). The conformance approach can relate objectives to impacts and provide more tangible results in measuring urban planning success by observing activities that have been done and identifying the characteristics of the object created (Talen 1997). At the same time, evaluation assesses the level of conformity of the real world with the urban plan. This research implements the conformance approach to tying urban plans with actual physical implementation using RRRs information derived from the urban planning and land administration processes.

2.2.3 Indicators for urban plan monitoring

The determination of relevant indicators is essential for the measurement of corrective actions. Von Stokar et al. (2001) arranged a set of indicators that must be defined for three purposes: continuous monitoring, evaluation of conformance for controlling, and comparing best practices as benchmarking. Determination of indicators is needed for the measurement of the success of the implementation of urban plans. Indicators shall cover social, economic, and environmental aspects. The environmental indicators address various pressures from human activities applied to the environment, both direct and indirect impacts. The societal response may refer to individual or collective actions to preserve and conserve the environment and resources. However, the construction of valuable and measurable indicators remains challenging because of unmeasurable indicators to judge urban planning's success and failure (OECD 1993 and Talen 1997). An indicator is defined as "*a parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon, environment, and area with a significance extending beyond that directly associated with a parameter value*" (OECD 1993). The OECD develops the Pressure-State-Response (PSR) framework based on a causality concept to understand the relationship of human-environment interaction (OECD 1993). In the PSR framework, measuring performance indicators uses a combination of environmental conditions, pressures, and societal responses. Faludi (1987, 107-112) argues that conformity analysis is under the influence of the subject and capable of assessing future conditions.

To some extent, the conformance approach may be similar to the ex-post approach in analyzing whether implementation goes according to the plan or not after it being implemented (Seasons 2002). In any scenario, indicators of urban plan monitoring must be observable and measurable. Government Regulation 15/2010 defines the step in performing technical and specific urban planning monitoring (Figure 2-2). Technical oversight is a regular activity for supervising the overall process of spatial planning. In contrast, specific oversight is the supervision of particular problems or violations in implementing the urban plan. A specific oversight comprises activities for validation and verification of information, technical analysis for these problems, and spatial planning violation. This regulation also specifies the result of the process in two possibilities:

compliance or inconsistency with the urban plan. Participatory urban plan monitoring requires all stakeholders to understand shared values and leverage participants' knowledge and skills to contribute LSK to urban plan monitoring initiatives to arrive at 'plan and progress' behavior. This study finds the conformity approach is suitable to answer two questions in urban plan monitoring: (1) was the urban plan followed, or is it being implemented by all stakeholders?; and (2) are the urban plan resulting in the desirable effects? This study develops indicators for participatory urban plan monitoring in eight possible zoning regulation violations and eight possible types of infringement in urban development (see Figure 2-2 and Table 2-3 & Table 2-4). Table 2-2 provides a sample of infringement represent in a matrix as shown in Table 2-4.

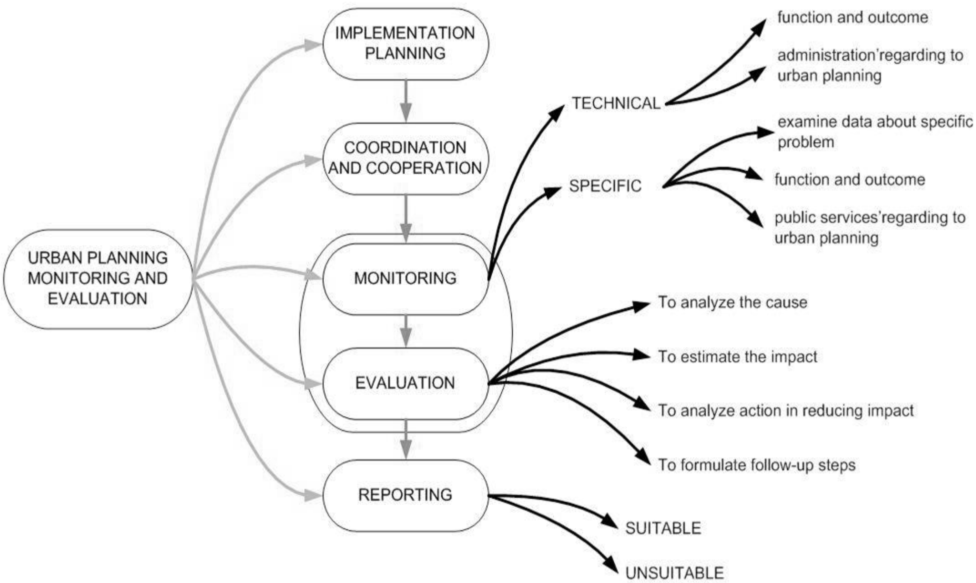

Figure 2-2. The workflow of the Urban Planning Monitoring Process in Indonesia (Government Regulation 15/2010 on Spatial Planning Implementation).

Table 2-3 Possible types of infringement in urban planning
(Source: Government Regulation No. 15/2010)

Type of infringement	Example
buffering boundaries	Build a house but exceeding river buffer boundaries
floor building coefficient	Build a two-story house but exceeding the floor building coefficient.
basic building coefficient	Build a two-story house, but the ratio of the sum of floor area exceeds the limit
basic green coefficient	Build a house, but the ratio of the green area is less than limit
partly inconsistent with land-use	Change function of part of a house into other types of prescribed land-use
full inconsistent with land-use	Change the function of a house into other types of prescribed land-use
fail to provide public facility	Lack or absence of hospital in a district as prescribed in the urban plan
fail to provide access	Lack or absence of access to the hospital in a district as prescribed in the urban plan

2

Table 2-4 Sample of a report of infringement of urban plan (Source: Government Regulation No. 15/2010)

Type of infringement	Zoning plan	Permit	Loss or damage/ fatality
Build a house without a permit on a green zone and causes no damage/fatality	×	×	×
Build a house without a permit on a green zone causes damage/fatality	×	×	✓
Build a house with a permit on a green zone without damage/fatality	×	✓	×
Build a house with a permit on a green zone and causes damage/fatality	×	✓	✓
Build a house without a permit in a residential area causes no damage/fatality	✓	×	×
Build a house without a permit on a residential area and causes damage/fatality	✓	×	✓
Build a house permit on a residential area and without damage to public property/fatality	✓	✓	×
Build a house with a permit on a residential area but causes damage/fatality	✓	✓	✓

2.3 Participatory urban plan monitoring

Urban planning in a democratic society should consider communication for sharing knowledge for action and ways of acting (Healey 1992). Later, Healey (2003) proposes a collaborative approach by integrating social theory in the process of urban planning, particularly on the implementation of plans (Healey 2003). As many cities already involve citizens in participatory urban planning, some collaborative approaches often encourage adversarial participation between government, organized interests, business, and citizens. Therefore, a city should facilitate authentic dialogue and improve networks and institutional capacity for a successful collaborative approach in urban planning to solve complex problems for future action (Innes & Booher 2004).

Participatory urban planning is not merely one-way communication but a multi-dimensional dialogue and interaction which enables learning and actions joined and competing interests to co-exist (Innes & Booher 2003). Therefore, communication and information are significant to urban planning to influence all stakeholders directly and indirectly (Innes 1998). In the conventional perspective of information in planning, policy- and decision-makers identified the problem while experts and planners generate information as a solution (Rein & White 1977 and Innes 1988). According to Innes & Boohler (2004), the new paradigm for participation uses information in a multi-way interaction in which power is distributed widely in society. In this setting, all stakeholders can communicate in formal and informal ways to influence action.

Utilizing local knowledge is vital for the whole urban planning process. Surprisingly, discussions of the participatory approach in monitoring urban plans are rare, let alone using a participatory approach for this purpose. Batty (2009) highlights the importance of cities having a sustainable urban information source for urban information. Goodchild (2007) addresses the potential of crowdsourced information from the citizens to fill the urban information gaps. This section provides a literature review of types of knowledge, motivations and roles, principles, and organization of participatory urban plan monitoring.

2.3.1 Local spatial knowledge

Local knowledge provides unique and ongoing knowledge, including local, practical, and expert knowledge are the key for urban plan monitoring. However, the definition of local knowledge is fuzzy and contestable (Silitoe 1998 and Grenier 1998). In 1979, Lindblom and Cohen defined local knowledge as "*knowledge that does not owe its origin, testing, degree of verification, truth, status, or currency to distinctive professional techniques, but rather to common sense, casual empiricism, or thoughtful speculation and analysis*" (Corburn 2003). Thrupp (1989) argues that local knowledge is dynamic to socio-economic and environmental changes. Local refers to a place, a region, a part of a region, or a route. In comparison, Dekens (2007) characterizes local knowledge as a system experiencing internal and external changes from a range of knowledge, including practices, beliefs, values, and perspectives in seeing the environment. In some conditions, using local knowledge is more reliable than scientific knowledge (McCall & Dunn 2011) and giving more comprehensive insights to localities (Dekens 2007, 7-9). McCall & Dunn (2011) noted that local citizens hold local knowledge over a specific geographic area. Therefore, inviting local citizens to participate in urban plan monitoring should be viewed within the broader context of livelihood and sustainability in the longer term. The broader and more diverse participants, the faster information and knowledge can be collected (Weiner et al. 2002 and Goodchild 2007), the more trusted the evaluation process and conclusions get (Patton 2008).

McCall & Dunn (2011) define Local Spatial Knowledge (LSK) as local knowledge representing spatial components. According to Minang & McCall (2006), Local Spatial Knowledge (LSK) offers a unique description of land and space, capable of identifying significant issues and encoding specific information of a particular area. However, the qualities of *crowdsourcing* (with multiple verifications and revisions by contributors and users) in spatial data is depending on trust (Callahan 2007, Kim & Lee 2019, Koehler & Koontz 2008), sufficient resources (Cardullo & Kitchin 2019, Irvin & Stansbury 2004, Lawrence & Deagen 2001 and Yang & Pandey 2011), transparency (Piotrowski & Liao 2012 and Stagars 2016) and reliable information-sharing mechanism (Ebdon & Franklin 2006, Olphert & Damodaran 2007, and Head 2007). LSK consists of technical knowledge, physical phenomena, tenurial information, and information about socio-cultural aspects (Grenier 1998, Minang & McCall 2005, and Dekens 2007). Participatory urban plan monitoring needs to accommodate LSK, particularly for their technical and cultural information associated with objects in urban areas. Further, LSK can relate urban development with land or space ownership, ecosystem services, and economic values in a particular area (Grenier 1998). For these reasons, citizens participation in urban plan monitoring is crucial in detecting, evaluating, and reporting phenomena, activities, or changes in an urban area, such as violation and infringement of urban plans, the threat to safety and health of citizens or ecosystems, or positive feedbacks of performance of urban planning. Citizens sharing their LSK in participatory monitoring is often found in disaster-related events, such as flooding (Le Coz et al. 2016, Assumpção et al. 2018), tsunami (Schlurmann et al. 2010 and Chatfield et al. 2013), earthquake (Oh et al. 2010, Guy et al. 2010, and Valecha et al. 2013), and climate change (Albert et al. 2012 and Brink & Wamsler 2018).

2.3.2 Working principles

There is a growing trend among policy-makers and planners to acknowledge the participatory approach in urban planning through collaboration with citizens or communities at the various stages (Cooke & Kothari 2001, McCall & Dunn 2011, and Lovan et al. 2017). In 1969, Sherry Arnstein laid the foundation for public involvement research and practices, emphasizing urban planning by putting citizens' control as ideal for local policy-making. According to Arnstein (1969), the objective of public engagement is the redistribution of power from contemporary power-holders (i.e., authorities) to the non or weaker power-holders (i.e., citizens or local community groups). She constructs "*a ladder with eight rungs*" metaphor for describing the typology of citizens' participation. These rungs are classified into three groups: lower, middle, and upper. The lower group is non-participation, which consists of manipulation, therapy, and informing. The middle group is tokenism, which comprises: informing, consultation, and placation. The upper group is citizen power, characterized by partnership, delegation, and citizen control. Wilcox (1994) provides a more straightforward classification with five levels of participation, but still helpful in characterizing information sharing for effective participation: (1) information; (2) consultation; (3) deciding together; (4) acting together; and (5) supporting local initiatives (see Table 2-5).

Table 2-5 Levels of participatory
(Source: Wilcox 1994)

Levels	Characteristics
Informing	Authorities provide information in one course of action without giving participants comments or feedback.
Consultation	Informing and giving participants the opportunity to comment and preferences in selecting solutions but not allowing them to develop ideas or play a role in action plans.
Deciding together	Informing and authorities share the power of creating and selecting solutions but not sharing the responsibility for implementing decisions.
Acting together	Informing and trusting, sharing a shared vision involving participant
Supporting local initiatives	Informing and providing adequate supports for independent community-based initiatives with access to funding.

According to Wilcox (1994), collaborative actions require information sharing, redistribution of power to achieve a shared vision, team building, design exercise, simulations, a structured organization for decision making, accountability, and operational for the longer term. The highest level of collaborative actions acknowledges that the ownership of a process belongs and is performed by the citizens. Land management is a human-environment interaction where local governments, businesses, and local citizens construct buildings, modify natural objects, or perform specific activities. A human-environment interaction has spatial consequences. Therefore, spatial thinking should also be introduced in urban plan monitoring to capture the phenomena, seek knowledge and develop solutions for undesirable impacts on socio, economic, and environmental aspects. The selection of spatial representation plays a critical role in determining the type of monitoring and selection of indicators on which location matters.

A suitable spatial representation provides better insights for stakeholders in the process of participatory urban plan monitoring. Spatial thinking describes stakeholders' understanding (experts, citizens, policy-makers) to represent, value, analyze, and decide over tangible or intangible phenomena or objects in a location. The Committee on Support for Thinking Spatially defines spatial thinking as "*a constructive amalgam of concepts of space, tools of representation, and reasoning processes*" (NRC 2006). National Research Council (1999) classifies five forms of spatial representation that play a pivotal role in understanding natural phenomena and people's behavior affecting the environment: visual, verbal, mathematical, digital, and cognitive representation (see Table 2-6). This Ph.D. research implements Wilcox's (1994) ladder of participation to accommodate collaborative action between authorities and citizens using their spatial thinking in participatory urban plan monitoring.

Table 2-6 Spatial representation dimension of geography's perspectives (Source: NRC 1999)

Spatial representation	**Functions**
Verbal	How to represent phenomena or activity through the detailed description in words (or audio).
Visual	How to represent phenomena or activity through hypermedia: maps, graphics, pictures, and audio-visual.
Mathematical	How to represent phenomena or activity through models of space, functional association modeling, and models of the process that address spatial interaction and change.
Digital	How to represent phenomena or activity by combining mathematical, visual, and analytics in digital forms.
Cognitive	How to represent phenomena or activity through mental maps or perception of behavior or environment from individuals or collectives.

Spatial thinking has always been and will be used in urban planning and land administration, particularly for looking at the dynamics of the world and synthesis domains. The synthesis domain describes how land management activities use and modify the biophysical environment that sustains life. It sees urban areas as a place, space, or scale for synthesizing human dynamics (i.e., social, economic, and political), human-environmental dynamics (human activities to the physical environments), and environmental dynamics (natural phenomena of a physical system). 3D representation and Geo-ICT and its combination are considered as innovations for cities to manage their land (and space) (LeGates et al. 2009 and Batty 2018). If this combination is shared with relevant stakeholders, it will improve their spatial thinking and cognitive ability to plan and manage a city (Roche 2014 & 2017). Murata (2004) demonstrates the potential of 3D spatial information for urban planning for several tasks: to visualize regulations in a complex urban setting, to compare the actual urban objects (e.g., building, public facilities) with regulation, to construct a simulation of the proposed urban development plans, and to facilitate consensus-building between stakeholders. Therefore, spatial thinking should also be used in all participation levels in urban plan monitoring (see Figure 2-3).

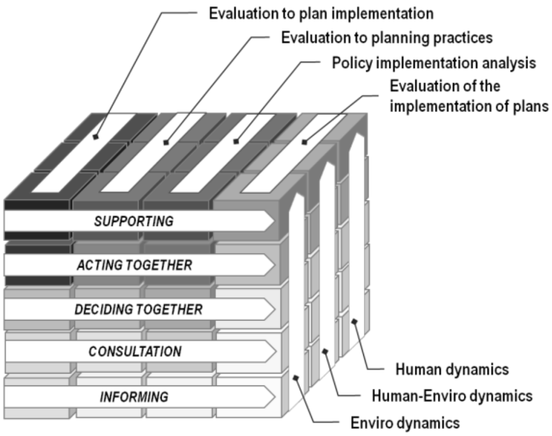

Figure 2-3. Combinations of spatial thinking in participatory urban plan monitoring (Adopted from Wilcox 1994, Talen 1997, and NRC 1999)

Enabling local citizens to access urban plans and share their LSK can help them understand how and why it works. Van Herzele & Wiedemann (2003) define principles suitable for participatory monitoring of the implementation of urban plans based on the theory of change. These principles are (1) citizen-based, (2) functional levels, (3) preconditions for use, (4) variety of qualities, and (5) multiple-use (See Table 2-7). The citizen-based principle addresses the priority of the citizens' strategic issues about an object to be monitored (i.e., basic social and economic requirements). Objects that are more likely to be monitored would have functional values, ranging from local to national. Successful participatory monitoring will depend on preconditions where objects that are located near, accessible, and safe are more likely to be covered. A local citizen may prioritize monitoring an object according to his/her preference for quality for activities or ability for multiple uses. By including citizens in urban plan monitoring activities, the facilitator should anticipate the spectrum of the participants' motivation to monitor an object depends and its qualities. Objects which are near and easy to access have a higher possibility of being monitored as a common precondition of use in participatory urban monitoring. Also, urban plan monitoring facilitators should prepare for multiple objects as citizens monitor meaningful or valuable objects.

Planning monitoring and planning evaluation are inseparable, particularly for making scenarios of solutions or planning corrective measures. The result of monitoring will be used as inputs for evaluation. Oliveira & Pinho (2011) define seven principles of planning evaluation (see Table 2-7). Evaluation is necessary for accountability and sustained assessments on planning products and results throughout the entire planning process (Alexander 2006 and Brody & Highfield 2005). Thus, the design of planning evaluation should refer to sound planning evaluation theory and best practices. Also, the selection of methodology of evaluation should enable the assessment and suitable for the specific purpose.

Table 2-7 Principles for participatory urban monitoring and planning evaluation.

Principles for participatory urban monitoring (Van Herzele & Wiedemann 2003)	**Principles for planning evaluation** (Oliveira & Pinho 2009)
1. Citizen based 2. Functional levels 3. Preconditions for use 4. Variety of qualities 5. Multiple-use	1. Planning practice and plan documents should be evaluated; 2. The design of an assessment methodology must be linked with planning evaluation theory; 3. The evaluation methodology should suit the object under appraisal; 4. The planning practice should be evaluated as a whole; 5. Evaluation and planning processes should be developed together, right from the beginning; 6. The evaluation process must have balanced development in time; and 7. The presentation of evaluation results and the analysis of their use by planning should be evaluated

Assessment of the planning practices should handle physical dimensions, integrate evaluation in all stages of the planning process, serve conformance and performance approach, and define judgment, learning, and interaction to activity (Oliveira & Pinho 2009). Planning evaluation is an integral part of planning processes and should be defined and performed in the whole process collaboratively. Oliveira & Pinho (2009) reiterate the importance of examining the presentation and usage of planning evaluation to find the right balance between technical knowledge and communication. The participatory monitoring and evaluation can support strategic and operational management, enable the generation and sharing of knowledge, empower local citizens, and provide accountability for the process (Woodhill 2005). Albrechts (2004) stated that transparency and accountability are the key concept of planning process in a democratic society. Consequently, participatory urban plan monitoring also prescribes all stakeholder to listen what citizens needs (Healey 1997). Therefore, transparency and accountability principles are the core of PUPM that ensure the right of citizens to access public information and allow input in matters affecting their interests at all levels (Albre chts 2004). Involvements of academia and experts from non-government organizations for overseeing the process and ensuring accountability may be vary in many countries but are preferred in participatory urban plan monitoring. Based on this logic and terms discussed in the previous sections, this research defines participatory urban plan monitoring as "*a continuous function that uses a systematic and collaborative collection of urban data on specific indicators to detect any inconsistencies in land development with urban plans*."

2.3.3 Motivation, roles, and types of stakeholders

Maslow (1943) proposes a hierarchy of 'human or communal needs and motivations to act' in five sets of interrelated goals: physiological, safety, love, esteem, and self-actualization. Physiological is vital to humans or the community to survive (i.e., water, air, food, cloth, and housing). Safety, the second level, represents the needs of humans or the community to secure its sustainability. The physiological and safety needs construct the basic needs for humans and the community. The "*need for love*" goal reflects humans' requirements to be accepted, loved, and belonged in an ecosystem, including friendship, family, society, community, and religion. The fourth is the esteem goal, which is the criteria for being appreciated, respected, and valued. The top-level is the "*self-actualization needs,*" which refers to an individual's requirement to achieve his/her full potential as a human being and community member. Participation of citizens in urban planning (including monitoring its implementation) contributes to all goals of Maslow's hierarchy of human motivation since it is vital to human survival, both directly and indirectly.

There are various motives and driving factors of landowners changing the function of land or space (Lambin et al. 2002 and Verburg et al. 2004). It is essential to characterize individuals' motivation to contribute information in the participatory approach, particularly for assessing the extent to which it will be included in urban plan monitoring. Coleman et al. (2009) identify eleven motives of spatial information contribution to evaluate credibility and reliability contributors: altruism, professional interest, intellectual stimulation, protection of investment, social reward, enhancement of reputation, self-expression, the pride of place, mischief, agenda, and malice. These motives must be addressed and anticipated in designing urban plan monitoring. However, local citizens will likely be willing to monitor urban plans for their basic needs and protect their investments (e.g., interest, safety, or livelihood). This study uses Coleman et al. (2009) classification to gauge the possibility of citizens' motivation to contribute and share their LSK in participatory urban plan monitoring (Table 2-8).

The Indonesian legal system acknowledges and encourages local citizens' spatial planning involvement by securing their roles, rights, and obligations. This acknowledgment departs from the limited space and the need for a harmonious spatial planning process in carrying out its objectives to create a safe, comfortable, productive, and sustainable livelihood. Spatial Planning Act (2007) empowers citizens in urban planning to access urban plans, object against authorities for termination of activities that deviate from plans, and file a claim for compensation against authorities or permit holders for losses caused by infringement urban plans. This Act also allows citizens to control the use of land and space according to urban plans. Government Regulation 68/2010 regulates forms and procedures for citizens' participation in spatial planning. In this regulation, local citizens can participate in controlling the implementation of urban plans. Local citizens have the right to submit criteria on zoning regulation, permit issuance, incentives, deterrents, and the imposition of sanctions. This regulation also allows citizens participation in monitoring and supervising the implementation of urban plans. Further, this regulation mandates local governments to develop and maintain information systems to facilitate data exchange between all stakeholders, including local citizens. This information system should help local citizens access information about the policy, plans and ongoing programs, urban plans, and control of land and urban space.

Table 2-8 Motivation of citizens in contributing LSK
(Source: Coleman et al. 2009)

Type	Purpose
Altruism	purely for the benefit of others
Professional interest	part of the job or personal project
Intellectual stimulation	enhancing technical skills, knowledge, and experience
Protection of investment	protecting or improving personal or common resources
Social reward	achieving a common purpose
Enhancement of reputation	enhancing personal or group reputation
Self-expression	earning personal or community esteem, respect, or self-worth
Pride of place	enhancing neighborhood reputation or publication
Mischief	generating skepticism or confusion
Agenda	providing biased information for specific interest

Malice	conducting criminal intent for personal or group gain

2.4 Summary

Batty (2012) highlights that observing, sensing, and monitoring are more than a means of generating urban information. It also provides a catalyst for the learning process of a city. Participatory urban plan monitoring is accommodating local knowledge and creating accountability, transparency, and inclusiveness in the whole urban planning process. The participatory approach in monitoring initiatives or plans may be in several forms. Many countries have spatial planning laws and regulations that govern citizens' involvement and outreaches in urban plan monitoring. Urban plan monitoring will involve examining property rights, which need some degree of supervision from authorities. This research will apply community-based monitoring for its collaborative actions between authorities and local citizens to sense, analyze, and report findings over time.

A participatory urban plan monitoring will gather LSKs representing actual conditions over the specific urban area compared with the urban plan. Seeger (2008) highlights that authorities can facilitate community-based monitoring to harness LSK to monitor the landscape planning process. Although the quality of participatory mapping results increases (Arsanjani et al. 2015 and Vandecasteele & Devillers 2015), it still needs additional efforts, such as quality control must be performed (Goodchild & Li 2012 and Mooney et al. 2010). Therefore, information delivery in monitoring the implementation of urban plans may expect specific information from local authorities and local citizens without neglecting other types of information proposed by the local community.

Citizens' participation in spatial planning is a right guaranteed by the constitution. At the operational level, local citizens' participation is regulated in the Spatial Planning Act (2006) and Government Regulation Number 68/2010. These regulations instruct the local government to provide information and tools for the society to perform urban plan monitoring. However, it will be more consistent and better ensure information integrity if the central government provides an information system for all local governments. In Indonesian cities, the dynamics of urban development are often infringing urban plans (Hastuti 2011). Therefore, local citizens must actively monitor and evaluate an urban plan to control land and space use according to the urban plan. Provision of access to information and a continual participatory approach is the way forward to improve awareness and understanding of local citizens about the importance of urban planning.

3

Assessing Spatial Information Themes for PUPM: Indonesian Cities[1]

This chapter presents a method to determine which spatial information to be shared among stakeholders and the spatial data specifications to support Participatory Urban Plan Monitoring (PUPM) in the Indonesian cities. Jakarta and Bandung were selected to represent the megapolitan cities. This study constructed a new method for selecting appropriate spatial information by considering regulation, functionality, and user-centric perspectives. These perspectives were quantified for the construction priority list for urban plan monitoring. The first sections of this chapter provide the context of participatory urban plan monitoring. Section 3.2 presents the role of spatial information in participatory urban plan monitoring. The development of a framework to select spatial information for PUPM is illustrated in Section 3.3. Section 3.4 addressed the requirements. Section 3.5 discusses the use of the proposed framework for assessing spatial information themes. The last section of this chapter presents our conclusion and future works.

3.1 Introduction

The UN's 2030 Agenda of Sustainable Development Goals (SDGs) features city and spatial information noticeably and explicitly (UN-GGIM 2017, UN-Habitat 2017, and Arnold et al. 2019). The localization of this agenda gives cities new targets that require a new approach in planning and practice. The localization of the SDGs raises several apposite questions that deserve critical examination, particularly to data, monitoring, and measurement of goals and indicators. Cities are demanded to provide and update physical and legal spatial datasets regularly. In developing countries, cities are struggling to provide up-to-date spatial information reflecting urban dynamics. Planners and decision-makers are still accustomed to primarily using demographic and statistical projection data to forecast urban changes (Marshal-Llacuna et al. 2011). According to UN-Habitat, the "*localization*" of SDGs in cities demands up-to-date spatial information to accommodate changes in planning, monitoring, and evaluation of urban planning. Urban changes are

[1] This chapter is based on the published paper in the International Journal of Geo-Information (Indrajit et al., 2019)

mainly the result of land utilization by societies, particularly in using their rights, restrictions, and responsibilities issues over specific land parcels (Van Oosterom et al. 2009). These issues have been identified and discussed by experts and authorities in land management, involving land tenure, land-use planning, land valuation, and land development. From this viewpoint, land-use changes need to be monitored, well-reported, documented, and analyzed using spatial information. By placing spatial information at the core monitoring system, land-use change can be produced and shared by stakeholders to assess sustainable development. Participatory mapping facilitates citizens in contributing their knowledge to the city government in the form of spatial information.

In facilitating participatory mapping, many cities established a '*top-down*' GIS system to support their decision-making (Jankowski & Nyerges 2001). Many of these '*top-down*' GIS applications were established based on spatial data producers' perspectives. They introduced only a limited dataset of topography and thematic maps to the participants. These systems were mainly developed based on the expert's view and, in many cases, marginalized Local Spatial Knowledge (LSK) (Harris & Weiner 1998). Sieber (2006) also reported that the '*top-down*' approach increases skepticism among participants. The potential role of citizens is, for example, underestimated. By giving access to spatial information services, citizens will enhance their knowledge in locating a phenomenon (Weiner et al. 2002) by filling in the information gaps with better quality for urban planning processes (McCall 2003). The rapid advancement of Geographic Information and Communication Technology (Geo-ICT) and open spatial information services enable citizens and non-government institutions to fill these gaps left open by government data (Goodchild 2007).

It is crucial to allow stakeholders to participate in defining the data specifications for participatory activities. Stakeholders in participatory urban plan monitoring should be given more responsibilities to access and determine the type and specification of spatial information and technologies to improve their LSK and comply with regulations (if any). This chapter assumes that regulatory demands and users' perspectives shall be integrated with functional requirements to support participatory urban plan monitoring. Participatory monitoring activities in urban planning require compliance with data specifications defined in regulations. We extended the Demand-Driven approach proposed by Malinowski and Zimanyi (2006) by creating three chains to accommodate regulations, as well as functional and user-centric requirements.

3.2 Spatial information in participatory urban plan monitoring

Spatial information is vital in urban monitoring (Calabrese et al. 2011 and Lee et al. 2006). According to Faludi (1989), an urban plan map should be regarded as an explicit reference for the city government's decision-making. This map will also be used as the baseline for calculating the costs and impacts of any violations or accidents. Yeh (1999) advocates that spatial information shall be used in determining the objectives, identification, and resource inventory in urban planning. He also added that a map is the most appropriate format for analyzing current situations, forecasting, presenting options in the urban planning process, and representing planning strategy for implementation, monitoring, evaluation, and monitoring. This chapter focuses on which features are needed by all participants to monitor the implementation of an urban plan.

Nyerges and Jankowski (2009) stated that land information, such as land rights, land value, and tax parcels, is required for decision-making to represent residential, public, parks and recreation, agricultural, industrial, and commercial uses. The available large-scale maps can make parcels' boundaries clearer to minimize the possibility of land conflicts. However, the current sensing technology-based approaches (i.e., remote sensing techniques and sensor networks, and so forth) can present only synoptic views over space and time (Sawaya et al. 2003). The synoptic view has difficulty in detecting non-physical changes (Taubenböck et al. 2014). Without the participatory approach, the local government must face a challenging task to survey directly on the ground. Improvement in providing required spatial information can be implemented into an open government initiative to introduce accountability into urban planning activities (Janssen 2010 and Rhodes 1997).

3.2.1 Policy and regulation

Regulation on spatial information sharing and policy on open data are essential in participatory urban planning. However, organizational culture influences the success of participatory monitoring initiatives. Citizens should be allowed to access, use, and contribute spatial information in public participation in urban planning. The law and policy will determine the scope of citizens' and non-government institutions' roles in monitoring urban planning processes. A critical factor in participatory urban plan monitoring is the legitimacy of spatial information produced by citizens or the power-holder and policy on communicating public information (McCall 2003). Whereas there is no legislation allowing citizens' involvement in urban planning monitoring, Non-Government Organizations (NGO) and community groups may implement the "*sidestep strategy*" to avoid the legal, policy, and cultural obstacles in accessing and contributing spatial information for Public Participatory in Geographic Information System (PPGIS) (Elwood et al. 2001).

Urban monitoring and evaluation activities need reference maps for all interested parties, including the regulator (the government) and the supervised party (the beneficiaries or the space developer). These maps are essential to reduce disputes over map-making. Van Loenen (2006) stated that fundamental datasets should be trusted, certified, and used as a reference in creating spatial information. Further, he argues that these datasets should be freely accessible to all stakeholders for various purposes. Freely accessible fundamental datasets can benefit the participatory urban plan monitoring to ensure the integrity of information. A framework dataset contains reference layers, such as topography and bathymetry, which provide a foundation for other spatial datasets. Urban zoning maps are eligible to be included in the framework dataset. They contain essential information, such as land-use permits, building location permit, infrastructure location permit, capacity and intensity of buildings and infrastructure, and zoning permit. Urban development plan maps contain various physical urban developments. This chapter presupposes that all stakeholders in participatory urban plan monitoring should be given free access to spatial information to produce better spatial information in urban plan monitoring. Many countries enforce zoning maps with regulations to be used as a reference for allocating public and private investment, land or space utilization, and urban development (McCall & Dunn 2011). In these countries, regulation may also contain an open data policy for the zoning map and the responsibility of the city government to inform land-use policy for socio-economic-environmental conservation activities, the issuance of the spatial use permit, the preparation of the building and environment plan, and the development of the infrastructure network plan.

3.2.2 VGI in urban plan monitoring and its quality

There is growing attention among city councils in developing countries to incorporate location and spatial knowledge in their decision-making (Chatfield & Brajawidagda 2013). These cities have primarily utilized Information and Communication Technology (ICT) and social media (Kamil 2015 and Valle-Cruz et al. 2015) to make cities smarter (Roche & Rajabifard. 2012). According to McCall and Dunn (2011), Geo-ICT enables citizens to translate spatial concepts of reality and their knowledge of phenomena into maps. Elwood (2008) reported that existing spatial information could not fulfill citizens' needs to perform their urban plan monitoring tasks. Nevertheless, there are success stories in organizing a *facilitated VGI* (f-VGI) by utilizing web mapping interfaces to allow citizens individually or collaboratively to contribute information on a map with a predefined set of criteria and specific geographical extent (Seeger 2008).

Participatory urban plan monitoring and evaluation aim to accommodate the local people or non-government organizations affected by urban planning processes (Seasons 2002). Michael Goodchild (2007 & 2009) proposed the concept of "*citizen sensor*" and the term "*Volunteered Geographic Information*" (VGI) for participatory mapping to collect real-world phenomena in the form of maps (spatial information) as a mental understanding of a specific area. The collaboration will stimulate accountability and will increase acceptance from the people by recognizing and translating their knowledge of object phenomena in the real world to produce urban information. By involving local people, the city government can improve the quantity of urban information and, at the same time, comply with the principles of SDGs (UN-GGIM 2017). Citizens or non-government institutions can step in as the external stakeholders to complement local government staff in participatory urban plan monitoring.

The quality of spatial information often hinders the citizens in contributing spatial information containing LSK (Brown & Fagerholm 2015). There are imperfections to be considered for spatial information produced by external stakeholders (e.g., VGI, participatory mapping), including fuzziness in classification and semantics, inconsistent scale, imprecision in boundaries and distances, spatial overlaps and gaps, and human senses preferences (Budhathoki & Haythornthwaite 2013; Goodchild & Li 2012; and Haklay 2010). Similar to the external stakeholders, Patton (2008) reported that the quality of monitoring performed by the internal stakeholders (authorities) might also be exposed to a personal bias, organization culture, and organizational politics. The external stakeholders are considered to have more motivation with a higher degree of neutrality, and therefore may neutralize this exposure. Lynam et al. (2007) reported that the absence of the georeferenced maps would influence the quality of VGI products, mainly to relate features to a location on the earth, to geometric accuracy, and completeness in attributes. The standard ISO 19157:2013—Geographic information—Data quality specifies data quality measures (ISO 2013). These are Positional Accuracy, Completeness, Thematic Accuracy, Temporal Accuracy, Logical Consistency, and Usability Element. This chapter considers only spatial information to meet these elements to be shared in participatory urban plan monitoring.

3.2.3 Common Operational Map

Participants in VGI initiatives have more knowledge of the local area, leading to better spatial information (Goodchild 2009). However, the VGI approach relies on access to the fundamental datasets (including ortho-imageries) provided by governments or global data providers. According to Talen (2000), sophisticated maps published by authorities or data providers may not be suitable for non-skilled citizens. The representation of these spatial maps contains technical information, which is too complicated to understand by local people contributing to participatory mapping activities (Elwood 2008 and McCall & Minang 2005). On the other hand, Google Earth and Google Map provide the success story for involving local people in interacting with online map visualization, utilizing topographic maps, aerial and satellite imagery, and enabling people to interact with spatial information and 3D city models.

To improve urban planning monitoring quality, the local government should also open their data and stimulate citizen participation to monitor urban changes—both physical and non-physical changes. The shared information helps minimize inefficiencies, create innovation and opportunities, avoid environmental degradations, enforce laws, and reduce social conflicts (Elwood 2008). A '*Common Operational Map*' (COM) can ensure the consistency between urban plan and reality and ensure the common perception of urban space between government and its citizens. LSK has the advantage of detecting urban dynamics and plays a crucial role in constructing COM. An accurate '*live map*' such as COM can be utilized as an effective communication medium for urban planning monitoring between governments, the permit holders, and affected parties.

3.3 Selection of spatial information themes for PUPM

The methodology applied in this study is adapted from Malinowski and Zimányi's (2006) approach on data selection in data warehouse design. This approach can accommodate the subjective and objective selection of required spatial information by considering three aspects: regulation, functional, and user-centric requirements to perform participatory urban plan monitoring. This chapter considers these aspects as three chains of requirements. The first chain corresponds to the regulation-driven approach and creates a specification as it emerges from urban planning regulation requirements. The second chain contains the scientific-driven approach and delivers a requirement that can be served from the existing information infrastructure. The last chain represents a user-centric flow derived from the requirement of participants in urban plan monitoring. Citizens are expected to utilize shared spatial information in participatory urban plan monitoring to capture real urban change based on their assessment. Therefore, the requirements of citizens as users in the PUPM system should be taken into account. Figure 3-1 shows the three-chain methodology schematically.

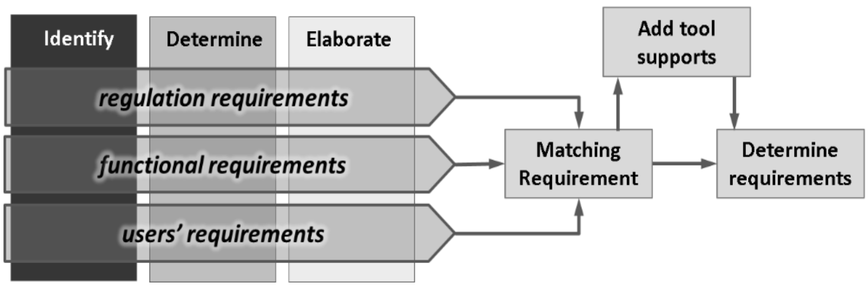

Figure 3-1. Methodology for determining requirements for spatial information services. Adapted from Malinowski and Zimányi (2006).

3.3.1 Regulation Chain

Technical data specifications may appear in the form of regulations or standards. Typically, a regulation is mandatory, whereas standards are voluntary (Timmermans & Epstein 2010). A government may enforce law or regulation for a successful implementation of policies (Eisenberg 2013). When referenced in a regulation, the use of standards can be mandatory (Knight 1995). Many countries are establishing their Spatial Planning Act to ensure conformity to specific norms or behaviors. Needham (2005) reported that regulation might increase the level of conformity stated in the central government at the expense of flexibilities at the lower jurisdictions.

3.3.2 Functional chain

The rapidly growing sensing technologies enable urban monitoring data production with higher quality on the positioning accuracy and thematic accuracy. However, sensing technology alone has limitations in determining the actual use of urban space. The challenge for local governments to harmonize urban improvement programs with urban planning is producing and synchronizing high-resolution databases in the planning activities and the city's project management. Meinel et al. (2001) stated that topographical maps to a scale of 1:5000 are sufficient for urban planning. Nyerges and Jankowski (2009) presented a theoretical framework to examine the functional requirements of spatial information for situational awareness. This framework contains five dimensions: functional activities, community conditions, decision process, spatial and temporal dimensions. Participatory urban plan monitoring is regarded as an effort to represent a complex city's complex problem by utilizing these dimensions.

It is vital to evaluate the nature of spatial information sharing for a city to develop a strategy for collaborative actions in collecting, processing, managing, visualizing, disseminating, and utilizing them. The decision is made from updates represented from these maps that will stimulate changes in mobility, water resources, and disaster management. Land-use maps and urban development maps are required to guide growth, correlate urban management with planning-, programming-, implementation level assessment, and promote a sustainable development perspective.

Nyerges and Jankowski (2009) proposed a "*phase–construct–aspect*" theory to measure spatial information utilization in assessing situational awareness to make a decision. The "*phase*" of a decision situation contains three steps: Design, Process, and Outcomes. "*Construct*" considers motivation from social-institutional mandates (or regulation), stakeholder's knowledge, and technology. "*Aspect*" represents the detailed characteristics of an object to be assessed. Based on this theory, this chapter associates the functional requirement of spatial information for participatory urban plan monitoring with utilizing these three levels of detail:

1. General urban planning assessment – Has spatial information helped to describe the spatial situation related to urban planning monitoring requirements?
2. Decision situation assessment by phase – Has spatial information been helpful in a phase-to-phase description associated with urban planning monitoring requirements?
3. Decision situation assessment by phase and construct – Has spatial information been helpful in describing all constructs within the phase associated with urban planning monitoring requirements?

The proper selection of spatial information shall improve contributors' visual and cognitive ability to perform participatory urban plan monitoring tasks. The presence of specific layers is essential for map-making as they enable users to perform orientation purposes or compare objects and understandability (Kingston et al. 2000). Rinner (2007) presented the importance of street layers for orientation. Today, urban spaces are often located in tall buildings, skyscrapers, and underground constructions. Logically, using the 3D city model and a 3D cadastre for navigation and developing the spatial relation of objects has increased. This chapter adopts the "*phase–construct–aspect*" theory as a functional chain for selecting layer selection to be used by ordinary citizens in contributing to participatory urban plan monitoring based on Nyerges and Jankowski (2009).

3.3.3 User-centered chain: requirements of stakeholders

The third chain is the user-centered chain. This chain shall support the identification of spatial information requirements for participatory urban plan monitoring from a user's perspective. Users in participatory urban planning can be categorized into two clusters: internal and external users. Internal users include city councils, city managers, and local government officials. Other users from public institutions included in this cluster are the central government (ministries and agencies) and provincial or state governments. The external users are users from non-government institutions, private sectors, and citizens.

3.4 Requirements for participatory urban plan monitoring in Indonesian cities

3.4.1 Regulatory requirements

Indonesia adopts the '*top-down*' approach for its urban (spatial) planning through the Spatial Planning Act (2007). The top-down spatial planning approach recognizes planning centralization, whether in a centralized plan or a referencing form. In contrast, the plan of the lower jurisdictions must follow the upper plan. This Act aims to achieve harmonious conditions between natural and artificial environments. The central government utilizes the Spatial Planning Act to ensure harmonious plans between jurisdictions (Hudalah & Woltjer 2007) (see Figure 3-2 &Figure 3-3). The Spatial Planning Act provides a solid legal foundation for Indonesian citizens to contribute spatial information in urban planning monitoring and evaluation and enable citizens to negotiate their interests with the power-holders (the government). Moreover, this Act also mandates that every land-use must be following the spatial plan, and the authorities must approve any land-use changes. The spatial Planning Act considers urban planning monitoring and evaluation as direct or indirect observation by stakeholders to assess urban planning through public reporting and formal documentation. According to this Act, the scope of monitoring and evaluating urban planning covers administrative, substance, and urban planning processes. Hence, the government must organize continuous monitoring and evaluation of land or space utilization.

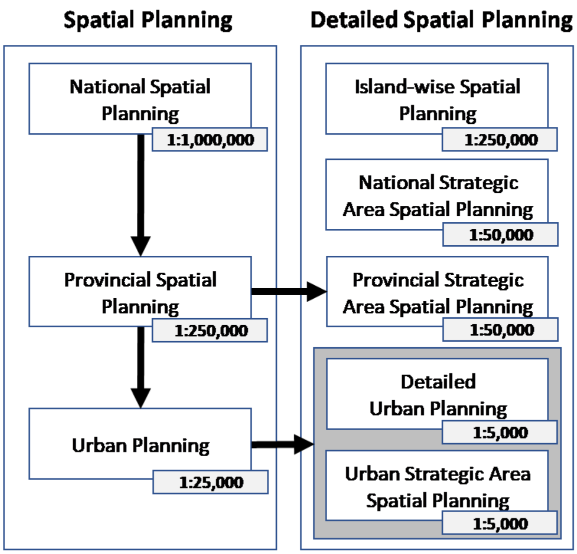

Figure 3-2. Detailed Urban Planning in the Indonesian Spatial Planning System (Minister of Public Work 2011).

Government Regulation on Spatial Planning Implementation (2010), the lower regulation on spatial planning implementation, instructs cities to develop a zoning map and the GISTARU system to support compilation, monitoring, and urban evaluation planning. The detailed specification of spatial information is shown in Table A-1 &Table A-2 in Appendix A. Spatial data quality is specified in Government Regulation 8/2013 on Accuracy of Spatial Plan Map. These regulations define criteria for the visualization of maps used in urban planning. The zoning map aims to ensure the optimal function of an area by providing criteria for the implementation (e.g., basic coefficient of the building, the basic coefficient of the floor, the height of the building, and basic coefficient of the green area). According to this regulation, a zoning map must contain a set of land or area functions, existing and planned urban infrastructure, and the intensity of each zone. The GISTARU system includes the relevant spatial information representing (existing) land-use and planned land-use (zoning plan). It should facilitate access to all stakeholders, particularly by the authority that is issuing the permit (license) and performing corrective actions or imposing a sanction.

3

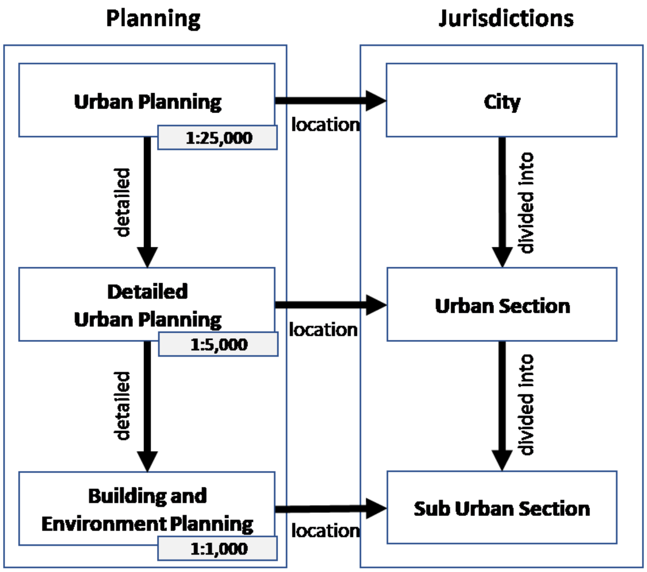

Figure 3-3. Hierarchy of spatial planning in Indonesia (Minister of Public Work 2011).

3.4.2 Functional requirement

In Indonesia, additional information is required to monitor specific functions, such as cultural heritage areas, disaster vulnerability areas, and safety areas of aerial transportation operations. Although the spatial planning implementation regulation specifies urban planning monitoring activities, spatial information specification has not been mentioned clearly. In reality, the city is free to include various maps based on producers' viewpoints to support urban planning monitoring and evaluation and for issuing permits and other purposes (Indrajit et al. 2018). The urban planning monitoring database should contain information representing urban change, including the location, type of urban change, and impact. The Geospatial Information Act (2011) and Government Regulation 9/2014 on the Implementation of Geospatial Information provide a legal basis for citizens to contribute spatial information. Government Regulation on Accuracy of Spatial Plan Map specifies some layers in fundamental datasets incorporated into the urban plan map via Spatial Information Infrastructure (SII) and other urban plan monitoring channels. This regulation also instructs the government to facilitate non-government institutions, businesses, and citizens in participating and contributing their spatial data through SII. Contributors and the citizens in PUPM have a minimum requirement of spatial information to perform a conformance approach in urban planning monitoring and analysis for generating a zoning violation report (see Figure 3-4 and Table 2-3 & Table 2-4 in Section 0).

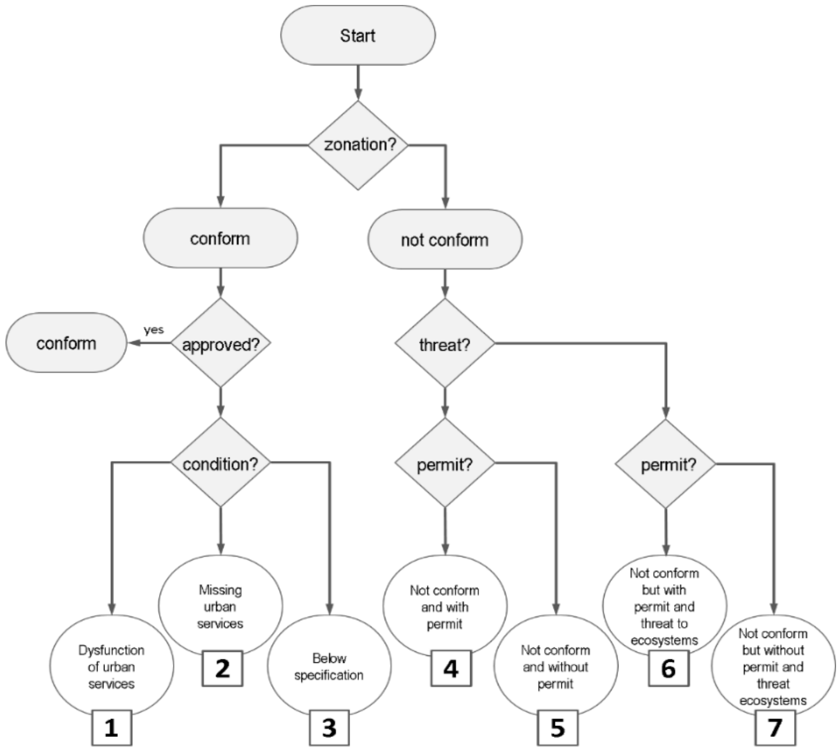

Figure 3-4. The workflow of conformance checking for urban plan monitoring (Government Regulation on Spatial Planning 15/2010)

3.4.3 User requirements

Government Regulation on Spatial Planning Implementation commands government institutions to perform urban planning monitoring and continuously facilitate citizen participation continuously. Stakeholders in urban planning monitoring may perform continuous, direct, and indirect observation or participate in urban plan monitoring. Participants may apply conformity assessment on actual space utilization using openly published zoning maps. If participants experience conformity to the zoning map and urban development plan, then they can validate the availability of necessary infrastructure and public services in that area. Suppose stakeholders find inconsistencies (or '*non-conformity*') with the zoning map and urban development plan. In that case, they shall examine the presence of a threat to the ecosystem or indication in the permit (Figure 3-4 and Table 2-3 & Table 2-4). This scenario may allow early detection of corruption if the observer finds a building permit inconsistent with the zoning plan map (result numbers 4 and 6 in Figure 3-4).

A pre-tested survey was conducted by interviewing urban planners, SII facilitators, and GIS professionals. The respondents were from *Badan Informasi Geospasial* (BIG), the national mapping agency (www.big.go.id), and academics from the Institute Technology of Bandung (www.itb.ac.id). A self-administered survey was performed to identify the user's perception of open data principles in participatory urban plan monitoring (see Table A-1 to Table A-3 in Appendix A). The survey targeted people with adequate knowledge, skills, and experience from local governments (city and provincial), central government, citizens, and non-government organizations. This chapter anticipates that the respondent had more experience in using 2D than 3D maps. The survey provided 80 filled questionnaires explaining officials from participating Indonesian SII members in the annual meeting in March 2017.

An online form was provided from March to June 2017. The survey yielded 89 successful samples, 62 samples from printed questionnaires, and 27 from online responses. After data collection, three interviews were conducted with three types of stakeholders for validation purposes. This study classified the respondents into seven groups based on occupation (central government, the provincial government, local government, private sector, non-government organizations, academia, and citizens) (see Figure 3-5). There are three roles identified: (1). data custodian, (2). urban planner, and (3). potential contributor (see Figure 3-6). The study found that organization types are represented in the survey; more government institutions responded than other groups. This study assumed potential contributors as citizens or persons affiliated with non-government institutions but motivated to perform participatory urban plan monitoring activities. By definition, a user's perspective on spatial information may contain personal bias, depending on knowledge, skills, and experience in utilizing spatial information. The citizens who responded are familiar with spatial information and urban planning and their ability to contribute to their LSK.

There is a possibility of urban planners and data custodians participating in urban planning monitoring as volunteers. Respondents were provided a list of questions (see Table A-3 in Annex A) containing spatial information types to be selected in performing participatory urban plan monitoring. From the questionnaire, most respondents were in favor of contributing to participatory urban plan monitoring. Eighty-nine percent of the respondents agreed to implement open data in participatory urban plan monitoring. Similar percentages of respondents accepted the citizen's involvements in this activity. Almost 65 percent of respondents were willing to share their personal information (e.g., name or address) in contributing to participatory urban plan monitoring. Further, 74 percent of respondents are willing to reuse spatial information from participatory urban plan monitoring.

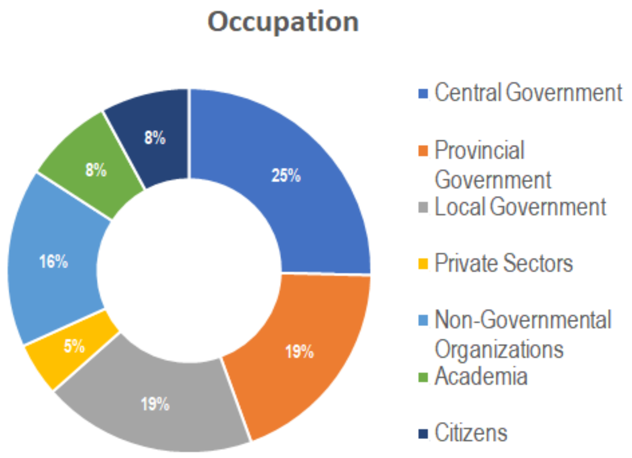

Figure 3-5 Respondents are based on affiliation (sectors).

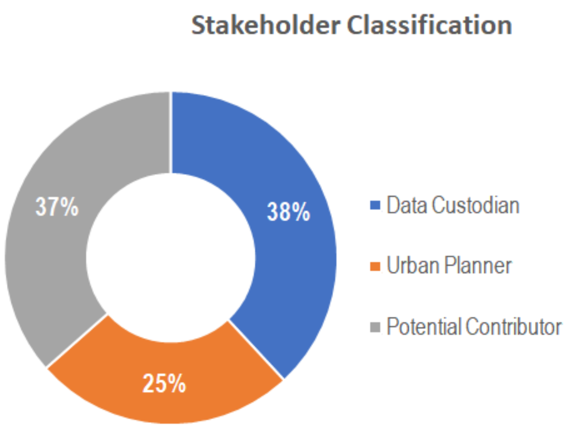

Figure 3-6. Respondents are based on actor roles derived from their affiliation.

An overwhelming amount of respondents need 3D spatial information and tools to improve spatial understanding to perform participatory urban plan monitoring (Figure 3-7). Most respondents (53 percent) required detailed spatial information (1–5 m) for urban planning monitoring, and 39 percent required very detailed (1cm– 1m) datasets (Figure 3-8). The survey also revealed that 61 percent of contributors expect the participatory urban plan monitoring system to provide detailed spatial information (1–5 m) for urban plan monitoring. Some respondents require even more detailed information (1cm– 1m) and streamed data (20 percent) for law enforcement-related actions.

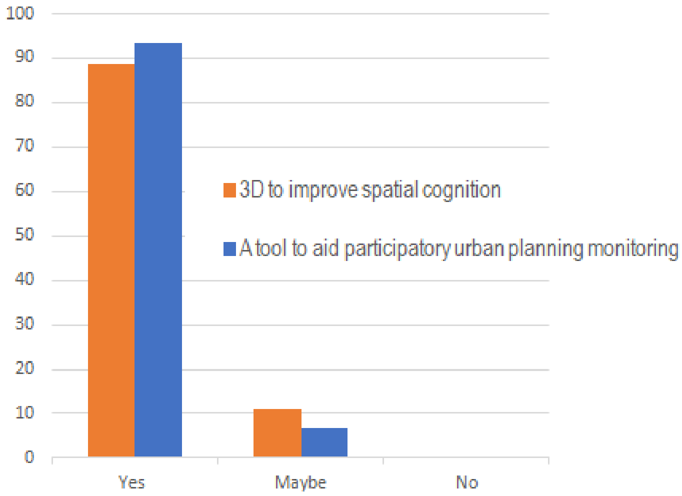

Figure 3-7. Type of spatial information needed

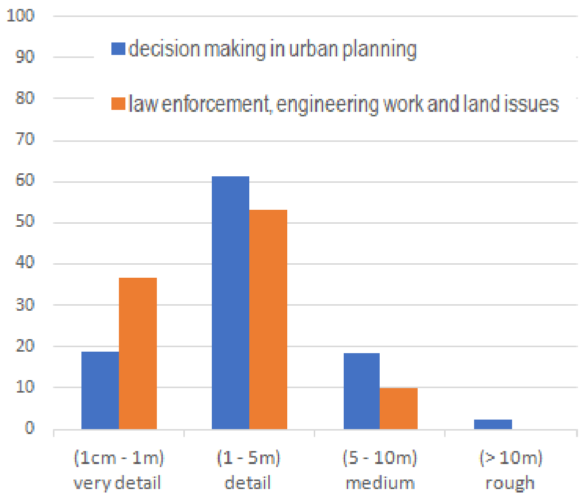

Figure 3-8. The expected quality of spatial information

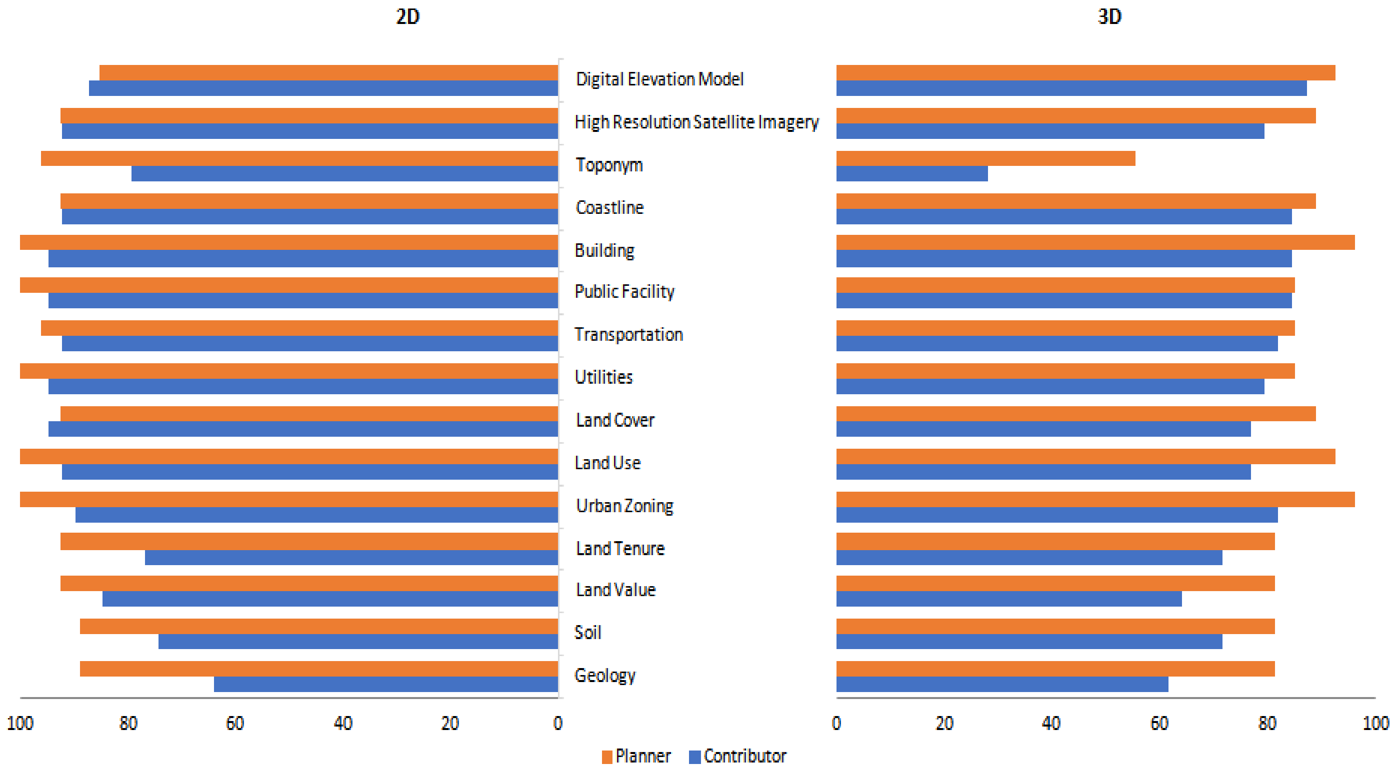

Figure 3-9 Spatial information to be used in participatory urban planning monitoring from the potential contributor (red) and urban planners (blue) (in percentages).

In Indonesia, the very detailed spatial information consists of maps at scale 1:2500 or better, while detailed maps fall between a scale of 1:2,500 to 1:10,000. More than 75 percent of the respondents indicated 2D high-resolution spatial information as (highly) relevant for PUPM: digital elevation model (hill shade), toponym, ortho-imageries, aerial photo, coastline, public facilities, transportation, utility, building, land cover, land-use, land tenure, urban zonation, and land value. According to the survey, these datasets should be shared and provided in participatory urban plan monitoring tools. There is 88 percent of the respondents demanding for 3D spatial information (see Figure 3-9). Approximately 75 percent of the potential contributors selected 3D high-resolution spatial information as relevant for PUPM. This response includes a digital elevation model (3D raster), ortho-imageries, aerial photos, buildings, public facilities, transportation, utilities, land cover, land-use, and urban zonation (see Figure 3-9).

3.5 Discussion

The spatial information requirement is designed to accommodate the contextual background for the findings on fitness for use to balance requirements directed from the regulation and functionality analysis. The selection method incorporates three requirements to support participatory urban plan monitoring, which is placed in three chains: regulation chain, functional use of spatial information chain, and a user-centered chain. A value of '1' was given for each category of spatial information that met the regulation and functional chain requirements criteria. This study added the percentage of all users that indicated a need for these datasets (see columns 7–12 in Table 3-1). Then, the total score is created by aggregating the scores from each chain. Assessment of spatial information requirements based on the regulation, functional, and user-centered chains of spatial information to perform the task requirements and conformance approach for PUPM in Jakarta and Bandung is explained in Table 3-1. The user-centered value was determined by three actors (planners, contributors, and providers). All respondents tended to select as many layers as possible in urban plan monitoring. There is a slight difference in preferences between urban planners and contributors (Table 3-1). The survey presents nine layers of 2D and eight layers of 3D spatial information scored more than 3.5, or more than two-thirds of the possible score (see the light grey area in Table 3-1). Nine layers are selected with 90 percent of possible values (see the dark grey area in Table 3-1). These layers are considered as critical layers to be provided in participatory urban plan monitoring.

3.5.1 Consistency between regulation and functional requirements

The selection of spatial information for urban planning processes is highly regulated in Indonesia, both in type and quality. For example, the National Transportation System map has to contain road network types at a scale of 1:5,000. These regulations have not included all stakeholders in developing a specification of spatial information.

Table 3-1 Score from three chains: regulation, functional, and user-centered requirements.

Layers	**Regulation**	**Functional**			**User-Centred**				**Score**			
		a	b	c	Planner		Contributor		Planner		Contributor	
					2D	3D	2D	3D	2D	3D	2D	3D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Public Facility	1.00	1.00	1.00	1.00	1.00	0.85	0.95	0.85	5.00	4.85	4.95	4.85
Building	1.00	1.00	1.00	1.00	1.00	0.96	0.95	0.85	5.00	4.96	4.95	4.85
Utilities	1.00	1.00	1.00	1.00	1.00	0.85	0.95	0.79	5.00	4.85	4.95	4.79
Land Cover	1.00	1.00	1.00	1.00	0.93	0.89	0.95	0.77	4.93	4.89	4.95	4.77
Coastline	1.00	1.00	1.00	1.00	0.93	0.89	0.92	0.85	4.93	4.89	4.92	4.85
Transportation	1.00	1.00	1.00	1.00	0.96	0.85	0.92	0.82	4.96	4.85	4.92	4.82
Land-use	1.00	1.00	1.00	1.00	1.00	0.93	0.92	0.77	5.00	4.93	4.92	4.77
Urban Zoning	1.00	1.00	1.00	1.00	1.00	0.96	0.90	0.82	5.00	4.96	4.90	4.82
Toponym	1.00	1.00	1.00	1.00	0.96	0.56	0.79	0.28	4.96	4.56	4.79	4.28
High Resolution Satellite Imagery	0	1.00	1.00	1.00	0.93	0.89	0.92	0.79	3.93	3.89	3.92	3.79
Digital Elevation Model	0	1.00	1.00	1.00	0.85	0.93	0.87	0.87	3.85	3.93	3.87	3.87
Land Value	1.00	0	1.00	1.00	0.93	0.81	0.85	0.64	3.93	3.81	3.85	3.64
Land Tenure	1.00	0	1.00	1.00	0.93	0.81	0.77	0.72	3.93	3.81	3.77	3.72
Soil	1.00	0	0	1.00	0.89	0.81	0.74	0.72	2.89	2.81	2.74	2.72
Geology	1.00	0	0	1.00	0.89	0.81	0.64	0.62	2.89	2.81	2.64	2.62

However, there is a consistency among regulations and between regulation and function of spatial information requirements and citizen participation. This study found that the Geospatial Information Act and Public Information Openness Act support the Spatial Planning Act in fulfilling the functional requirement of participatory urban plan monitoring. The harmony between regulation and functional aspects has simplified the construction of spatial information requirements for urban planning monitoring and governance in spatial information management.

3.5.2 The importance of GIS knowledge in user-centered requirements

However, some respondents identified as contributors had difficulty relating spatial information to a specific task in participatory urban plan monitoring. It is consistent with Nyerges and Jankowski (2009) that assessing a decision by 'phase–construct–aspect' will require a detailed understanding of the whole urban planning process to select spatial information requirements. Spatial information shared in participatory urban plan monitoring should assist contributors in performing these tasks by:

a) Describing the general situation in urban planning (column 3 in Table 3-1). Spatial information was designed to be used only to represent the real-world situation and to assist in navigation, orientation, and simple assessment. The potential contributors should select some layers, such as water bodies, toponyms, transportation, utilities, buildings, public facilities, land-use, land tenure, administrative boundary, urban zonation, aerial ortho-photo, and satellite imagery be used for urban plan monitoring.

b) Providing information for phase and task outcomes in urban planning (column 4 in Table 3-1). Decision assessment by phase requires a spatial representation of the real world as well as information of the object in urban development. Potential contributors recognized the importance of land cover, land suitability, urban plan maps, critical area, and disaster risk information to assess urban planning.

c) Providing arguments in problem representation of urban planning (column 5 in Table 3-1). A conformance approach in decision situations by the phase-construct assessment approach requires spatial information. Particularly in decision assessment by phase and additional maps for representing characteristics of phase in urban development to perform a specific function in urban plan monitoring.

3.5.3 Determination of spatial information requirements

Most cities, including Jakarta and Bandung, are lacking of resources to perform urban plan monitoring in Indonesian cases. Local governments are often overwhelmed with the need to produce adequate information in monitoring the urban dynamics in densely populated cities, particularly for Jakarta and Bandung. They have limited resources, personnel, and budget to perform continuous observations. Moreover, these local governments have often failed to perform self-evaluations of urban planning implementation, particularly in identifying urban changes that failed to conform to the requirements. Although the Spatial Planning Act (2007) and government regulations require spatial information at a general level, it is still tricky for contributors, especially citizens, to select them because of lack of detail. Developing specifications for spatial information based on regulations is considered similar to the phase–construct decision approach. From these findings, the regulation aspect is suitable for the supply-driven for participatory urban plan monitoring.

This chapter recommends the supply-demand–driven approach, based on Malinowski and Zimányi (2006), to assess the relationship between three aspects (regulation, functions, and user-centered aspects) in spatial information requirements. Facilitators and system developers should consider regulation (if any) and functional aspects in providing spatial information, developing tools for participatory urban plan monitoring, and assessing stakeholders' preferences for selecting spatial information. Further, the supply–demand-driven approach can be used to construct a priority list for spatial information services in a participatory monitoring system according to a specific task.

3.5.4 Summary

There are twelve thematic themes (see Table 3-1) that score more than three from the proposed selection method. If the authority defines data specifications in a regulation-based functional aspect, their value will be consistent. We can use the proposed method to analyze the consistency between the functional and regulation requirements chains. We found that participants are very receptive to 3D spatial information. However, part of this selection method (user-centered chain) is still exposed to biases since each respondent has different skills and knowledge in selecting appropriate data.

3.6 Conclusions

The provision of spatial information to support the localization of the SDGs poses significant challenges. Cities have to prioritize a new approach in providing the new fundamental dataset in monitoring urban planning and its practice. Indonesian cities should develop a new strategy to provide up-to-date spatial information to support critical problem-solving in urban development and achieve goals and indicators prescribed in the SDGs. Planners and decision-makers have broadened their attention not only on statistical data but also on spatial information to predict urban growth. This shifting is essential for sustainable development in cities and monitoring stakeholders using their rights, restrictions, and responsibilities over their land and spaces. This chapter aimed to help facilitators and system developers of VGI select spatial themes in developing an application interface for participatory activities. In many cases, facilitators share data via their application in a Facilitated-Voluntary Geographic Information (f-VGI) based on a data producer's point of view only, disregarding regulation, functional, or user's requirements.

This chapter proposes to include three chains for constructing data specifications: regulation, functional, and user-centered. The three chains can be considered the new approach to determine urban plan requirements since facilitators or app developers disregard one or more chains. In most cases, they provide spatial data in their application based on their assumptions, ignoring a holistic understanding of the PUPM system, including users' needs. In Jakarta, Open Street Map provides road networks and points of interest in their F-VGI for participatory flood mapping. However, data on utility networks and drainage layers (sewers and canals) are not provided and identified as causing the flooding (Majcher 2014). In a similar case in Bandung city, the local government published a mobile GIS-based "*Panic Button*" application, an F-VGI, for reporting crime by sharing Google Map layers only. In this interface, they omit police station distribution (Bandung City 2017). This chapter offers a method to determine which spatial information to be shared with all stakeholders and the spatial data specifications to support PUPM in Indonesian cities.

3.6.1 Developing a selection method

This chapter successfully introduced a new method to select spatial information priorities to be shared with stakeholders to support PUPM in the Indonesian cities of Jakarta and Bandung. This method addresses the spatial information requirements from three chains or sources: the requirements from regulation, requirements from a functional perspective, and user requirements. The first chain derives the spatial information specifications as specified in urban planning regulations. The second chain contains the spatial information requirements for PUPM, as described in the literature. The last chain provides the requirements of the actual users in participatory urban plan monitoring. A variety of criteria can examine each of the chains. In reality, not all layers needed are available in appropriate quality (geometry, temporal, and thematic). Therefore, this method can reformulate the criteria to examine which spatial information is suitable for participatory urban plan monitoring.

3.6.2 Does spatial information determined by regulation meet contributor demands?

This chapter shows that the availability of spatial information services is essential in performing participatory urban plan monitoring. The selection method has successfully selected nine layers that are critical for PUPM in two Indonesian cities. These datasets need to be available and shared among all stakeholders in participatory urban plan monitoring to successfully monitor urban planning. Spatial information mentioned in the regulation is not the only source available. When shared with participatory urban planning monitoring contributors, it is helpful to perform conformance evaluations by comparing them to reality. If the spatial information is shared with external parties, they can monitor, evaluate, and report whether reality conforms to the urban plan.

3.6.3 Implications and future research direction

In her well-known article, Arnstein (1969) suggests that sharing information is essential for participatory activities. Thus, Open Government Data is essential in PUPM and has real potential to improve the LSK of stakeholders. The idea of open government at the city level is to promote democratic principles by enabling interested citizens to access information and become contributors in a meaningful way to their neighborhoods. Today, many cities are settling into participatory or collaborative activities as part of the SII initiative. The emergence of open data and the SII allows society to participate in urban development. Most of the initiatives seem to expand open data towards and beyond the Internet of Things (IoT) and harvest quality citizen contributions. However, amidst open data and smarter city initiatives being developed, many fundamental challenges in providing spatial information have appeared. This chapter recommends that the selection method be implemented to analyze the suitability of spatial information shared in the SII. As the open data movement gains momentum, a higher participation level needs to be applied in a data-sharing system in cities. The Open SII has real potential to be integrated into a smart city ecosystem, particularly for accessing and contributing large-scale maps and 3D spatial information. Furthermore, spatial information support for participatory planning monitoring is not valid in urban areas; it is also valuable in rural areas and fulfills the 2030 Agenda of Sustainable Development.

4

Developing A Spatial Plan Information Package in ISO 19152 LADM[2]

This chapter presupposes that all stakeholders are entitled to have a complete view of land-related information sourced from both spatial planning and land administration. This chapter presents the Spatial Plan Information Package to standardize spatial plans to ensure interoperability and better integration among land information. This package was developed within ISO 19152:2012 on the Land Administration Domain Model (LADM) to define essential information containing land administration and spatial planning components. One of the primary objectives of the LADM is to document and share RRRs for those who are entitled to or have interests in land or spaces. This chapter proposes integrating the RRRs information from the spatial planning and land administration within the LADM standard. This chapter includes a study of the standardization of spatial plans in European countries and Indonesia. Section 4.1 illustrates the importance of spatial plan information interoperability while a holistic perspective on spatial planning in integrating sectoral policies in Section 4.2. The State of the Art of Land Administration System (LAS) and its relation to spatial planning are described in Section 4.3. We present our findings and the design of a spatial plan information package for the LADM in Section 4.4. In Section 4.5, the proposed package is discussed, and a country profile is presented as an example of the implementation of the spatial plan information package provided. Section 4.6 concludes this chapter.

4.1 Introduction

Rapid urbanization leads to rising pressure on urban areas. Cities need to improve their land management practices to maintain their economic growth sustainably. At the same time, proper land management preserves social harmony and environmental sustainability. Anticipating this challenge, the UN (2015) puts land management at the center of its 2030 Agenda for Sustainable Development Goals (SDGs). As Corbett & Mellouli (2017) point out, urban areas should prepare to host SDGs' great battle. Nowadays, many local governments adopt the sustainable cities model (Hall & Tewdwr-Jones 2010). A holistic

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2 This chapter is based on the published paper in the Land-use Policy Journal (Indrajit et al., 2020)

view of integrating different spatial planning priorities, using a triangular model of society, economy, and environment (Campbell 1996). Identifying the existing Rights, Restrictions, and Responsibilities (RRRs) of each stakeholder is essential in the spatial planning process (McLoughlin 1969 and Enemark et al. 2014). For policymaking, governments at all levels also require a continuous inflow of (real-time) land-related information to reflect land use dynamics.

4.2 Land Administration System and spatial planning

Land Administration Systems support allocating and securing land or space rights, conducting cadastral surveys, transferring the rights in land from one party to another through sale or lease, and conflict management regarding land rights and boundaries (Enemark 2005 and Van Oosterom 2013). However, a complete view of information about people and their land needs also to accommodate restrictions and responsibilities on land or 3D space. This view is essential for sustainable land use and needs to be represented and shared with the public. A Land Administration System (LAS) should provide and manage this kind of information. Further, a well-managed LAS shall support land tenure, land value, land use, and land development (UN-GGIM 2015). For two decades, the International Federation of Surveyors (FIG) acknowledges LA as "*the processes of determining, recording and disseminating information about the tenure, value, and use of land when implementing land management policies*" (UN-ECE 1996). Countries establish LAS to manage land-related information as framework datasets or key registers (Van Loenen 2006 and Van Oosterom et al. 2009) through a Spatial Information Infrastructure (SII).

The UN has acknowledged the urgency for member nations to have an information system for managing land-related information. Following this recognition, the UN and FIG (1999) highlight the role of LAS and the SII to facilitate the sharing of information among government institutions and to the citizens in supporting land management. The 2030 Agenda for sustainable development implicitly calls for a commitment to the use of information technology and enables all stakeholders to participate in land administration and spatial planning to protect rights, improve lives, and ensure better land management (UN 2015). Many countries have strengthened spatial planning by enforcing regulations to ensure policies into reality (Nadin & Stead 2008, Hudalah & Woltjer 2007). Information about land ownership, land-use policy, and RRRs is vital in spatial planning processes, particularly in densely and intensive spaces, particularly in the urban area. Therefore, authorities should improve their LAS by integrating RRRs resulting from land administration and spatial planning processes. Authorities should facilitate access to land-related information for businesses and citizens through the SII and enable the multidimensional representation of RRRs.

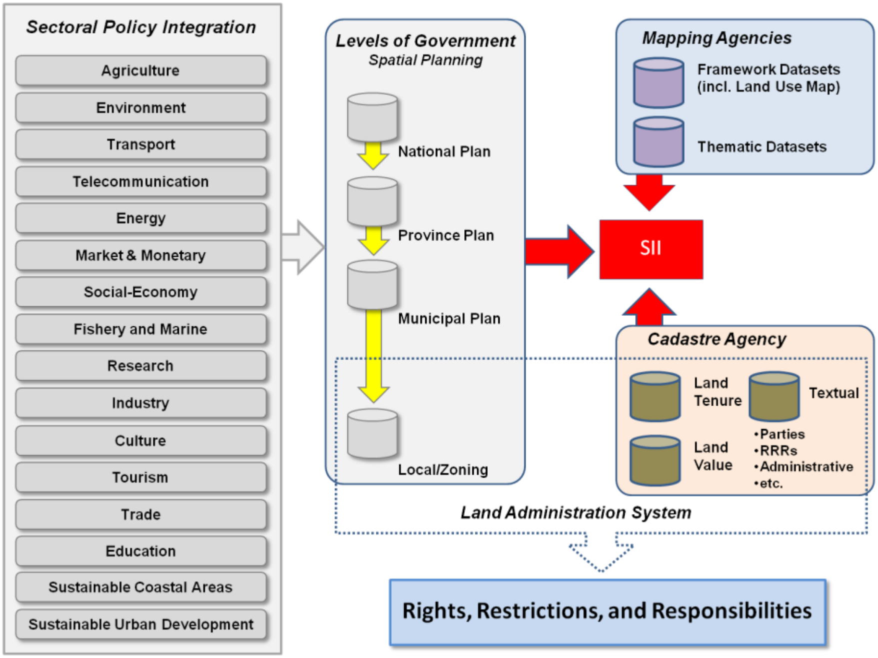
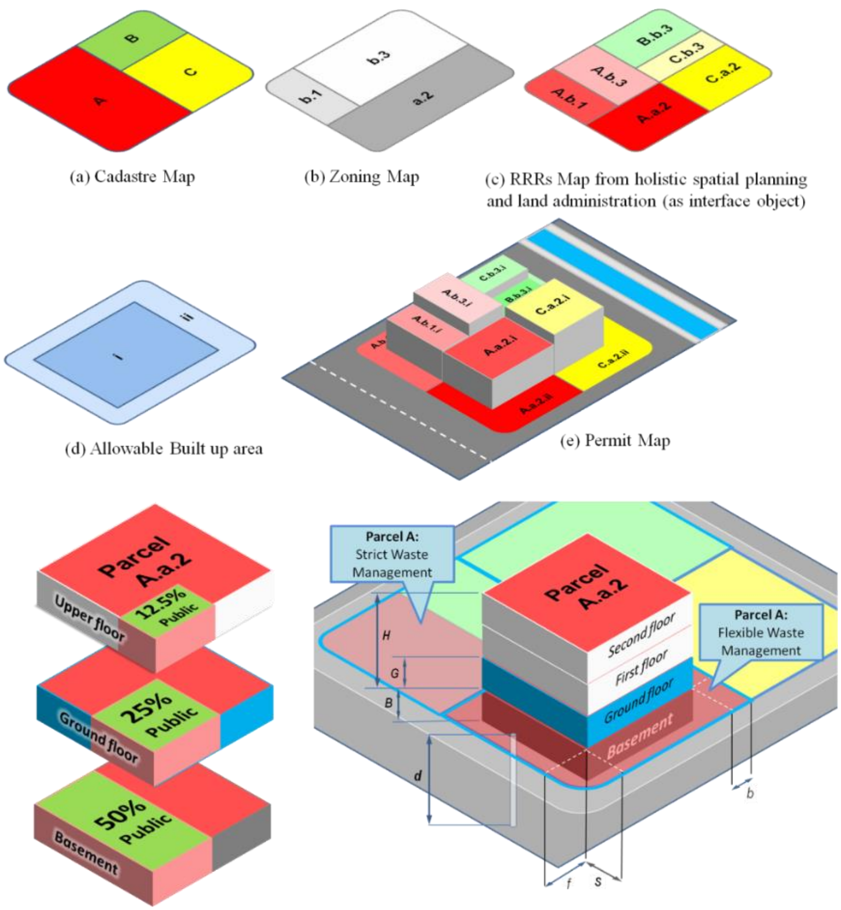


Figure 4-1. A holistic approach to Spatial Planning in Indonesia.
Land Administration System and Spatial Information Infrastructure (SII) can support land-use management and Spatial Planning (Red arrows).

Many countries have categorized the cadastral and spatial plan maps as fundamental datasets in their SIIs (Van Oosterom et al. 2009; Campagna & Craglia 2012). Better understanding and re-use of land-related information can be achieved with the standardization approach that ensures unambiguous definitions, consistency, and integrity of information within the SII (Van Oosterom et al. 2009). This standardization can be done using the standard spatial reference (e.g., topographic maps) shared by the mapping authority and cadastral agency (red arrows in Figure 4-1). Consequently, it is imperative for land tenure and spatial planning to be interoperable and standardized to secure land administration goals (Enemark et al. 2005) (see the dashed box in Figure 4-1). FIG (1995) recommends that LAS to provide an up-to-date record of the relationship between people and land, including land allocation, subdivision, or consolidation. Since spatial planning also leads to RRRs on a land parcel, it is crucial to consider 3D and temporal aspects in zoning objects to better representing the zoning regulation (see Van Oosterom and Stoter 2010). LAS (building on the SII) should have the 3D and temporal capabilities to represent valid geometric and time-bound information about RRRs to the landowners, investors, and authorities, including information about permissions, prohibitions, obligations, and incentives sourced from the spatial planning process.



(a) Cadastre Map (b) Zoning Map (c) RRRs Map from holistic spatial planning and land administration (as interface object)

(d) Allowable Built up area (e) Permit Map

(f) Example of volume-based criteria for public services allocation in each floor of a building in a specific zoning plan on parcel A.a.2

(g) Illustration of a height-based restriction and waste management policies in a 3D RRRs on a land parcel A.a.2 where blue lines represent parcel boundary.

Figure 4-2. Integration spatial planning and cadastre for constructing 3D RRRs.

It is typical for authorities to enforce spatial planning through legally binding zoning policies and permits. The sectoral policy integration is implemented in land-use programs that provide a foundation for comprehensive planning on land parcel levels (see Figure 4-2). Each of these sectors may represent its policy on spatial information or in text. The spatial plan is derived from land-related information, such as the cadastre map, land-use map, zoning map, development plan map, and a land value map. There are many cases where the information from the land registry (Figure 4-2.a) and the zoning plan (Figure 4-2.b) impose various restrictions on a land parcel or sub-parcel (Figure 4-2.c). In this case, restrictions and responsibilities depend on specific land use (e.g., factory, commercials) (Figure 4-2.d). City governments may use the cadastre map and the zoning map to construct responsibilities derived from permits (Figure 4-2.e). Examples are an obligation to preserve water, an obligation to preserve open space on a parcel (Koomen et al. 2008), prescribing a set of responsibilities to prevent and mitigate natural and artificial hazards (Fell et al. 2008) or to contribute to the environment, biodiversity, and quality of life (Geneletti et al. 2007). There is an increasing demand for cities and municipalities to provide complete and updated land-related information in a competitive and interconnected world. Specific ratios and intricate arrangements in a land parcel need to be well defined, particularly in a mixed-use case (Figure 4-2.f). Integration of spatial planning and land administration can provide a complete overview of the legal situation of a land parcel or urban space. This overview may contain information on tenurial rights, restrictions of activities for landowners, and responsibilities for all stakeholders. Restrictions can be physical, such as building height limits (H), ground floor height (G), basement depth (B), groundwater access depth limit (d) (see Figure 4-2.g). The integration also facilitates determining the maximum buildable area on a specific land parcel; side free distance (s), distance to road centerline (r), front free distance (f), and back free distance (b) (see Figure 4-2.g). It is indisputable that a spatial plan should be included in LAS and shared with the landowners and businesses. This inclusion of spatial planning into LAS will provide an updated zoning regulation to construct more complete RRRs, crucial for all stakeholders in decision-making on land or spaces. The spatial dimensions are becoming more and more critical, especially in dense urban areas, involving multiple uses of space (Louw & Bruinsma 2006; Groetelaers & Ploeger 2007).

Many countries and cities are working on the standardization of land-related information and developing a 3D cadastre (Van Oosterom 2013) to provide more realistic, secure, and sustainable RRRs over land and space in a sophisticated setting. There are three possible strategies to improve the level of interoperability between spatial planning and land administration. The first (a) strategy is not to standardize spatial plan information and regard it as a document or source as part of the existing LADM (Figure 4-3). In applying this strategy, the spatial plan will be unstructured and difficult to represent and visualize RRRs in a more realistic format, particularly for multistory or high-rise buildings and complicated sectoral policies in an urban area (see Figure 4-2.g). A second (b) strategy is to construct a new ISO standard for the spatial planning domain model (light blue box) (Figure 4-3.b). The new standard should refer to the LADM classes for representing RRRs in the spatial planning process (circle and square). Developing a new standard is a challenging task, involving a series of complex procedures, takes considerable time, and requires involvement from experts worldwide (ISO 2012). The third (c) strategy is to introduce a spatial plan information package (dashed blue box in Figure 4-3.c) into the LADM (green box) as an extension of ISO 19152:2012.

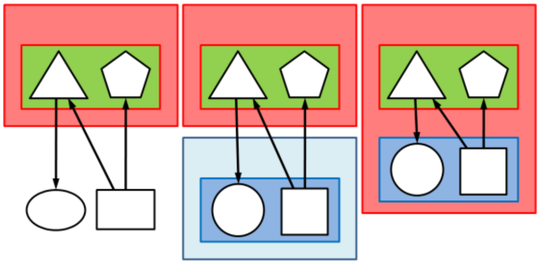


Figure 4-3. Strategies for improving interoperability of spatial plan (spatial and textual): from the current the LADM standard without spatial planning (a) towards the new LADM standard including spatial planning (c)

This chapter attempts to ensure interoperability between spatial planning and land administration by adding a spatial plan information package into the LADM to improve interoperability. Land administration information and spatial plans are produced from the different government sectors and avoid redundancy in the form of the same features coming from a different process. This strategy will simplify objects used in cadastre and spatial planning by reusing existing LA classes for both applications. The main reason to propose spatial planning information into a package as an improvement of ISO 19152:2012 is practicality and efficiency in achieving interoperability. Also, by introducing spatial planning as a package of the LADM, users can see more comprehensive and realistic information about RRRs for land management activities. This chapter incorporates both the characteristics of spatial planning of developed and developing countries to construct the new spatial plan information package into the LADM.

4.2.1 Development of spatial planning data model in developed countries: European countries

Directive 2007/2/EC establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) (INSPIRE 2007) and legislation directly stemming from INSPIRE addresses the interoperability of spatial plan. The INSPIRE legislative suite provides spatial plan standards in five areas: Metadata, Data Specifications, Network Services, Data and Service Sharing, and Monitoring and Reporting. The INSPIRE defines a spatial plan as "*a set of documents that indicates a strategic direction for the development of a given geographic area, states the policies, priorities, programs and land allocations that will implement the strategic direction and influence the distribution of people and activities in spaces of various scales*" (EC 2007). Both spatial planning datasets and official documents are facilitated in the INSPIRE's planned land-use conceptual schema (Figure 4-4).

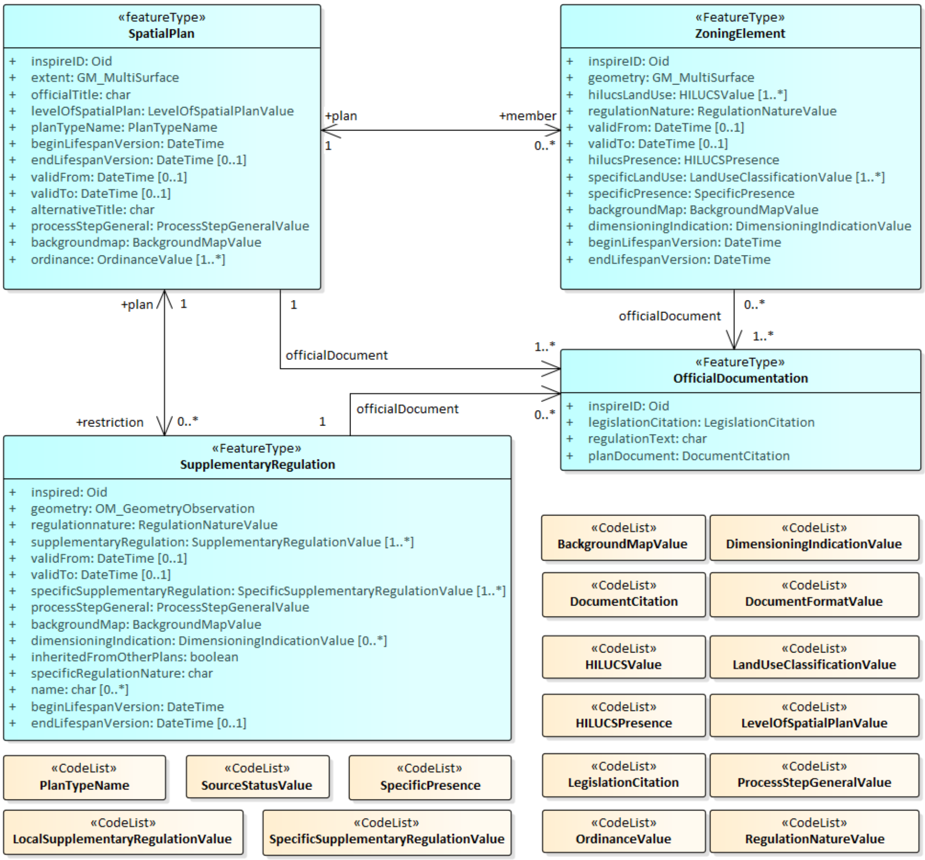


Figure 4-4. Overview of INSPIRE's Planned Land-use schema (INSPIRE, 2012).

There are two main classes in INSPIRE's Planned Land-Use data model: *SpatialPlan* and *ZoningElement*. These classes contain geometry and information related to spatial planning. The *SpatialPlan* class consists of the characteristic of the spatial plan as attributes (*planTypeName* and *levelOfSpatialPlan*) and legally binding documents. *ZoningElement* is part of *SpatialPlan*, representing a zoning plan on a specific area or space. The *ZoningElement* class facilitates detailed regulation on land parcel level. This class provides sectoral policy integration of land-use through *hilucsLandUse* and *regulationNature* (see Figure 4-4). A *HILUCSValue* is provided in the form of a codelist to ensure semantic interoperability within the INSPIRE registry (INSPIRE 2012). Semantic interoperability attempts to resolve semantic differences between peoples, languages, cultures, and countries. Both government and landowners can use a *regulationNature* attribute in *ZoningElement* class to correspond with spatial planning regulation. The INSPIRE planned land-use data model also provides *SupplementaryRegulation*, a *FeatureType* that contains documents and criteria determined by zoning regulation. *SupplementaryRegulation* contains valuable information for stakeholders about obligation, prohibition, or permission attached to a specific land.

In 2009, the European Union (EU) initiated the *Plan4All* project to achieve the interoperability of spatial plans (Murgante et al. 2011). Plan4All model distinguishes current land-use and planned land-use (spatial plan). This project proposes two main classes in the Plan Information group: *PlanObject* and *PlanFeature*. *PlanObject* consists of geometric information of the spatial plan of an area (Čerba, 2010). Plan4All's spatial planning data model considers *PlanFeature* as a subgroup of *PlanObject*. The *PlanObject* class provides geometry, textual, and administrative/process information for spatial planning. The *PlanFeature* class accommodates land-use indications on a specific area, such as status, type of regulation imposed on, references, and criteria. These indications will be imposed on each lot and parcels. *Plan4All* project has not yet prescribed a minimum geometric unit of the spatial plan (i.e., land parcel), but the area covered by *PlanFeature* may correspond with many land parcels or, in some cases, with none. The Administrative Information group represents administrative situation and process in spatial planning (parties, date of adoption, steps of the spatial planning process, legal validity). A specification of the paper-based outputs is facilitated in the Graphical Information group, while Textual Information contains the textual part of a spatial plan.

4.2.2 LAS and spatial plan information system in developing countries: Indonesia

Land administration in Indonesia is governed by the Basic Agrarian Principles Act (1960) and has three components: land registers (written legal instruments), cadastral mapping, and land registration. Through the National Land Agency (*Badan Pertanahan Nasional*/BPN), Indonesia's government develops and maintains land administration information, which is considered part of cadastre: land parcels, land tenure, and land value. Until 2018, the land registration program has covered 51 million out of 126 million land parcels (KSP 2018). However, in this program, BPN only records rights in land (including landowners). The ministries and local governments hold information on most restrictions and responsibilities within the spatial planning and sectoral database system. BPN established the *Komputerisasi Kantor Pertanahan*/KKP (Computerized Land Office) as the National Land Information System in 1997. Since then, BPN continues several initiatives in improving NLIS with a focus on automation. The current KKP (KKP-web) version is managed centrally by the Center of Land Data and Information, a governmental unit under the BPN organization. Following the national geoportal establishment in 2011, BPN is improving the KKP system gradually.

As a formal response to the publication of ISO 19152:2012, BPN initiated the gradual migration of the national parcel database toward compliance with the LADM packages (Pinuji 2016). Further, the current KKP database system was built based on the BPN interpretation of the LADM. A prototype of Indonesia's LADM profile has been developed and presented in ISO 19152:2012 as Annex (ISO 2012). According to the Spatial Planning Act (2007), the government is responsible for managing space and natural resources in an integrated manner. This law divides spatial planning into a hierarchy similar to administrative leveling (Figure 4-5). Spatial planning at the provincial and municipal levels prepares and establishes a spatial plan containing spatial structure (urban development) and zoning policy. The spatial structure plan contains existing and planned infrastructure to support socio-economic activities, while the zoning plan regulates the distribution of functions.

The Spatial Planning Act, Local Government Act (2014), and Capital Investment Act (2007) instruct the local government to establish a GIS for Spatial Planning (GISTARU) and to disseminate spatial plans. Spatial zoning is used as a reference to include criteria for developing physical infrastructure and activities in using a space or a land parcel. The integration of land-related information is mandated in the Capital Investment Act for simplifying permit issuances (Deloitte 2018). This Act instructs government institutions explicitly to integrate the process of approving and issuing permits. The urgency for interoperability is recharged by the Online Single Submission (OSS) regulation, which mandates the government to develop a system that incorporates spatial planning and land administration information. The OSS system is expected to ensure access to land-related information supporting the acceleration of business permit issuance. Spatial information plays a critical role in the core of the OSS system, particularly for location permits, land ownership registration, spatial planning compliance, and environmental assessments to assist both the authorities and investors in obtaining information for investment submission. To some extent, this information describes Rights, Restrictions, and Responsibilities (RRRs) on a land parcel of space (see Table 4-1). The authorities configured Land Administration and Spatial Planning systems to support permits on a parcel and business licensing. However, these systems contain information that is classified as public information. Indonesian citizens' rights to access information are protected by the Constitution and laws and regulations, namely the Basic Agrarian Principle Act, Spatial Planning Act, Protection and Management of Environment Law (2009), and Public Information Disclosure Act (2008). In reality, authorities, businesses, and citizens still struggle to provide a complete overview of the RRRs. Silos of information often hinder landowners or investors in prospecting and transferring land rights (see the National SII in Figure 4-5). Interoperability is the key to integrate land-related information, especially in providing complete RRRs from KKP and GISTARU. However, many local governments have difficulty accessing and understanding land-related information from KKP due to the absence of unambiguous protocol and lack of information infrastructure. This situation makes it difficult for GISTARU to fully support the local government in managing land and space (Pinuji 2016). This is all closely related to land administration.

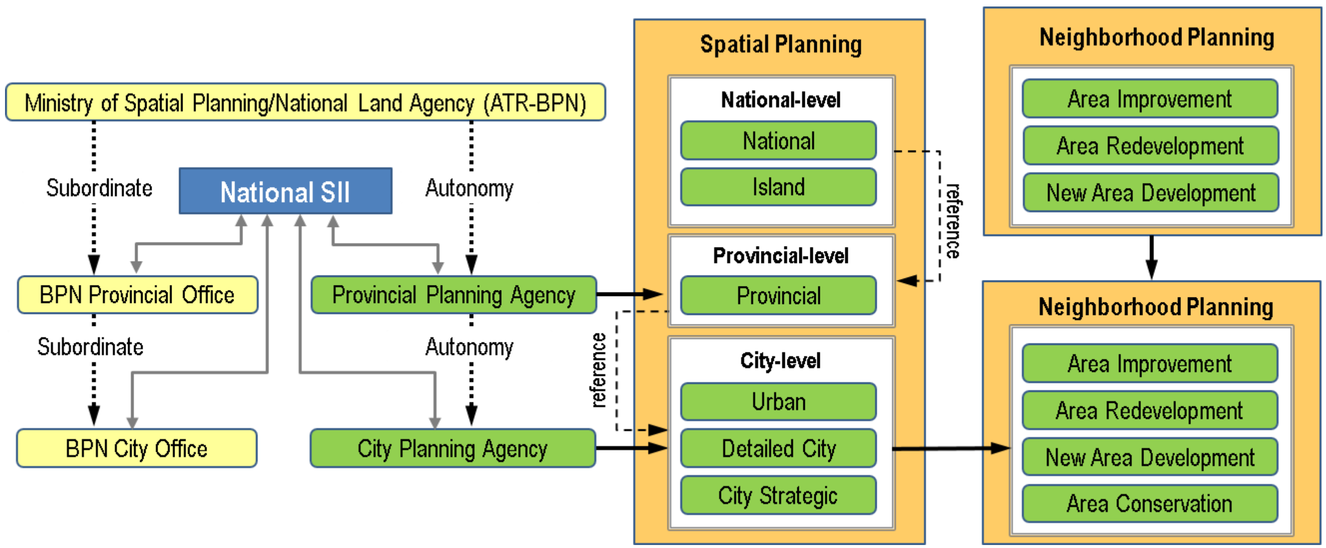


Figure 4-5. **Hierarchy in Indonesian Spatial Planning**
Based on Spatial Planning Act No. 26 (2007) and Government Regulation No. 15 (2010), Green boxes are under supervision of local governments, Yellow is the Central Government (BPN), Blue is National SII initiative (BIG).

Table 4-1. RRRs Information in the Spatial Planning Information System (Jakarta) (Source: Province of DKI Jakarta 2012)

EN Colum	Detail
ID_SubBlock	Identifier of sub-block
SubZone	Spatial Planning Sub Zone
Zone	Spatial Planning Zone
BuildingBaseCoefficient (percent) (KDB)	A percentage number comparison between the entire building floor area can be built with the available land area. KDB is determined from a roofed room area with a wall of more than 1.2 m and projected buildings. If the projected area has a height of less than 1.2 m, KDB will count 50% with a record not exceeding 10% of the specified KDB value.
FloorBuildingCoefficient (percent) (KLB)	A percentage of comparisons between the total areas of all building floors can be built with the available land area.
FloorAmountBuilding (floor) (KB)	The limit of the number of building floors. If the vertical distance between floors is more than 5 m, then the height of the building is considered as two floors, except for the use of lobby rooms, or meeting rooms in commercial buildings (including hotels, offices, and shops)
BasicGreenCoefficient (ratio) (KDH)	The ratio between open space outside the building for reforestation against an area of parcels. Natural open space is part of the space outside the building that is not covered by concrete, or there is no barrier for water to seep into the ground.
BuildingBasementCoefficient (percent) (KTB)	A percentage number comparison between the area of the footprint and the area of parcel/controlled space.
IntensityType (Tipe)	Limitation of the intensity of building according to a parcel.
IntensityPatternType (PSL)	An intensity pattern grouping in a neighborhood according to the city plan.
ZoningArrangementType (TPZ)	The level of flexibility towards the general provisions of the Zoning Regulations (*Pengaturan Zonasi/PZ*) and the basis for providing incentives for development.
RoadDemarcationLine (meter) (GSJ)	The distance from the road centerline to the front yard fence is allowed to be established. Authorities define demarcation lines for installing water, electricity, gas, and sewerage along the GSJ. Buildings cannot be erected on GSJ unless the GSJ coincides with the building boundary line (GSB).
BuildingFrontDemarcation Line (meter) (GSM)	A demarcation line for developing a building on a parcel. This line limits the physical building to the front, back, or side. The width of the GSB is calculated as one-quarter of the width of the Road-Owned Area (*Daerah Milik Jalan/DMJ*) and drawn from the boundary of the Fence Line (GSP). For trading areas and commercial services, the minimum GSB is 5 m from the GSP boundary.
BuildingSideDemarcation Line (meter) (GSS)	A demarcation line that limits the closest distance to the side or rear boundary of a land parcel. GSB is calculated from the boundary line to the outer or rear outline of a building that functions as space and safety factors.

The existing country profile of Indonesia of ISO 19152:2012 can be improved by introducing a complete and integrated representation of RRRs for BPN. At this moment, most restrictions and responsibilities are managed in a separate information system (see Figure 4-5). Currently, BPN is implementing 3D information at the operational level for apartments, commercial, and high-rise buildings (Suhattanto 2018). It transforms its 2D geometric description of the land parcel and RRR into a 3D representation (Hendriatiningsih et al. 2007 and Safitri et al. 2016). In 2016, the Government of Jakarta developed 3D *SiPraja*, a 3D visualization model for spatial planning using ESRI technology (Figure 4-6). The 3D *Sipraja* implements a 3D aspect to preserve and present spatial plans to its citizens in a more realistic format. A 3D spatial planning model is implemented mainly to visualize floor building coefficient (*Koefisien Lantai Bangunan*/KLB) and building height (*Ketinggian Bangunan*/KB), which require height information and 3D views. However, this model was not developed based on the LADM as the purpose is to visualize spatial planning in 3D to provide better navigation and cognitive understanding for the user.

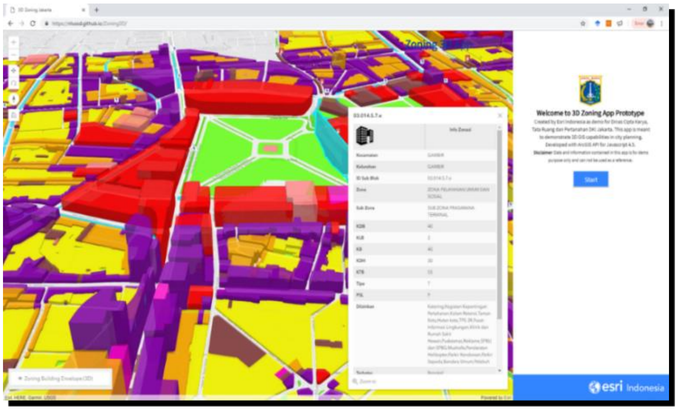


Figure 4-6. 3D *SiPraja*- A prototype for of 3D urban planning of Jakarta (available online through https://nlussd.github.io/Zoning3D/)

4.3 Spatial Plan Information Package in the LADM

Lemmen et al. (2013) note that a LAS requires a standardized domain model to deal with its complexity and interoperability to use and re-use land-related information. The ISO 19152:2012 specifies references covering essential information components to develop, implement, and efficiently maintain LAS. The LADM standard aims to enable combining land information from different sources coherently (ISO 2012). The LADM contains abstract and conceptual models with four packages that identify parcels, documents, persons, transactions, and other land administration issues (Figure 4-7). As a spatial domain standard, the LADM provides a shared ontology used as a primary standard for many aspects of land administration, such as geometry, temporal, metadata, observation, and measurements from cadastral survey and mapping activities. These aspects will be used in LAS to register land rights and assist land-use control, land development, and land valuation. RRR derived from the spatial plan will be based on individual and collective rights, privileges, restrictions, and responsibilities.

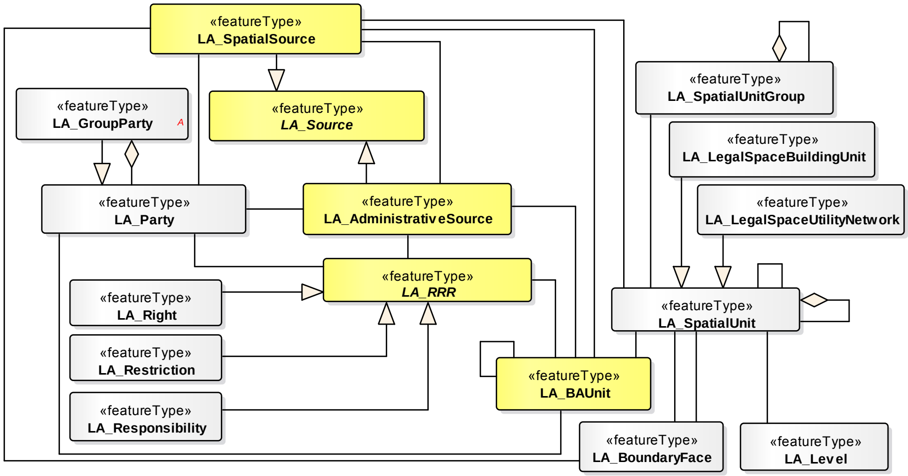


Figure 4-7. Overview of classes in the Land Administration Domain Model

Spatial representations and temporal aspects in public laws may be classified into advantages, restrictions (prohibitions), and responsibilities (obligations) into restriction and responsibility classes. Paasch et al. (2015) propose an extended abstraction of RRRs based on European countries' type of interest. The new spatial package as an extension of the LADM provides a complete relationship between land and people. It contains spatial plan information in three main classes: *SP_PlanBlock*, *SP_PlanGroup*, and *SP_PlanUnit* (Figure 4-8). Re-use of existing land administration classes will maximize the integration of spatial plans into the LADM. Both *SP_PlanBlock* and *SP_PlanUnit* have geometry to represent sectoral policy integration through spatial planning processes. *SP_PlanBlock* contains the spatial plan resulted from spatial planning processes. These plans guide city/municipal governments to construct a zoning/detailed plan. The *SP_PlanUnit* represents the zoning/detailed plan as *featureType* to accommodate sectoral policy integration criteria. A zoning plan refers to a spatial plan (in most cases). Both are legally binding for all stakeholders. The *SP_PlanGroup* class accommodates the aggregation and referencing mechanism in the hierarchical setting of spatial planning from all spatial planning levels, namely national plan, provincial plan, and city/municipality plan. In reality, *SP_PlanBlock* is represented by a spatial plan map, while the *SP_PlanUnit* refers to the zoning map (Figure 4-8). Overall classes proposed in Spatial Plan Information Package are explained in Table 4-2.

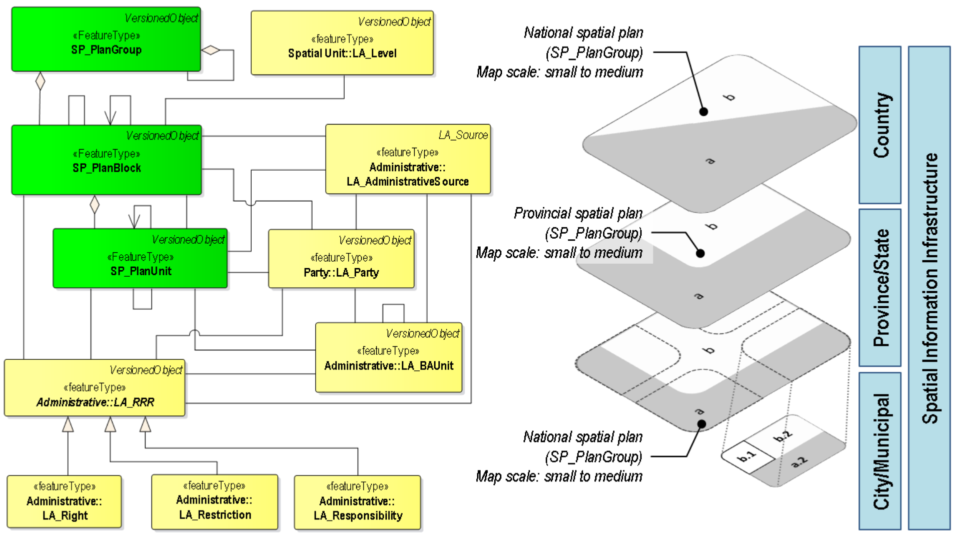


Figure 4-8. Classes in a spatial planning package *SP_PlanBlock*; *SP_PlanUnit*; and *SP_PlanGroup*.

4

The LADM consists of five basic packages (ISO 2012) that ensure LAS standardization and capable of representing RRRs in 2D and 3D. Van Oosterom & Stoter (2010) advocate that the LADM also considers 3D (spatial) and 4D (temporal) dimensions in the representation of cadastral objects. Knowing that spatial planning also leads to RRRs on a land parcel, it is crucial to consider the 3D and 4D aspects in zoning objects to ensure optimal zoning regulation. The proposed spatial plan information package can represent spatial planning results dealing with the visualization of 3D zoning objects on, above, or below the earth's surface (Figure 4-9). *SP_PlanUnit* class contains the geometry of the zoning plan, both in 2D and 3D, while *VersionedObject* stores its temporal information. The changes regarding spatial representations and sectoral policies that occur on the 3D zoning objects should be recorded continuously to prevent conflicts, disputes, or fraud.

A local government may update the zoning plan in responding to socio-economic and environmental changes, such as political adjustment, natural disasters, and climate changes. Increasing pressure on urban areas needs awareness of the importance of the development, and maintaining 3D urban information could raise the concept of 4D urban planning. Consequently, the 4D representation of zoning regulations will increase the spatial plan's usability by providing better insight and will, therefore, reduce conflicts over the zoning object. The proposed spatial plan information package in the LADM can facilitate the representation of various sectoral policies in geometry (3D zoning objects on, above, and below earth surface) and official documents containing the policies attached to a specific area (Figure 4-9).

Table 4-2 Classes in Spatial Plan Information Package

Class (Stereotype)	Detail	Type
SP_PlanBlock	A class contains "Polygon" to a characterized boundary of the planned land-use policy of an area. Typical representations are *Residential Area*, *Commercial*, and *Industry*.	(*FeatureType*)
SP_PlanUnit	A class is containing "Polygon" to the characterized boundary of the zoning plan of an area. Typical representations are *High-Density Residential Area*, *Banking*, and *Heavy Industry*.	(*FeatureType*)
SP_PlanGroup	A class representing the hierarchy in spatial planning	(*FeatureType*)
SP_EasementType	A list of rights to do an activity or use a land parcel or space owned by others for specified purposes.	(*Codelist*)
SP_ProtectedClassification Value	A list about the type of protected area	(*Codelist*)
SP_RestrictionZone	A list about the type of restriction in doing an activity or using or developing a specific building on a land parcel or space.	(*Codelist*)
SP_PermitType	A list of intensity in doing an activity or using or developing a particular building on a land parcel or space.	(*Codelist*)
SP_HeightIndication	A list of height indication or limit of height of a building on a specific area	(*Codelist*)
SP_SurfaceIndication	A list of area indication or limit of the size of a building on a specific area	(*Codelist*)
SP_VolumeIndication	A list of volume indication or limit of the volume of a building on a specific area	(*Codelist*)
SP_SpaceFunction	A list of the type of function on a specific area	(*Codelist*)
SP_Sub space function	A list about the type of function of a building on the specific area	(*Codelist*)
SP_StatusType	A list of the type of states of usage of a land parcel or space.	(*Codelist*)

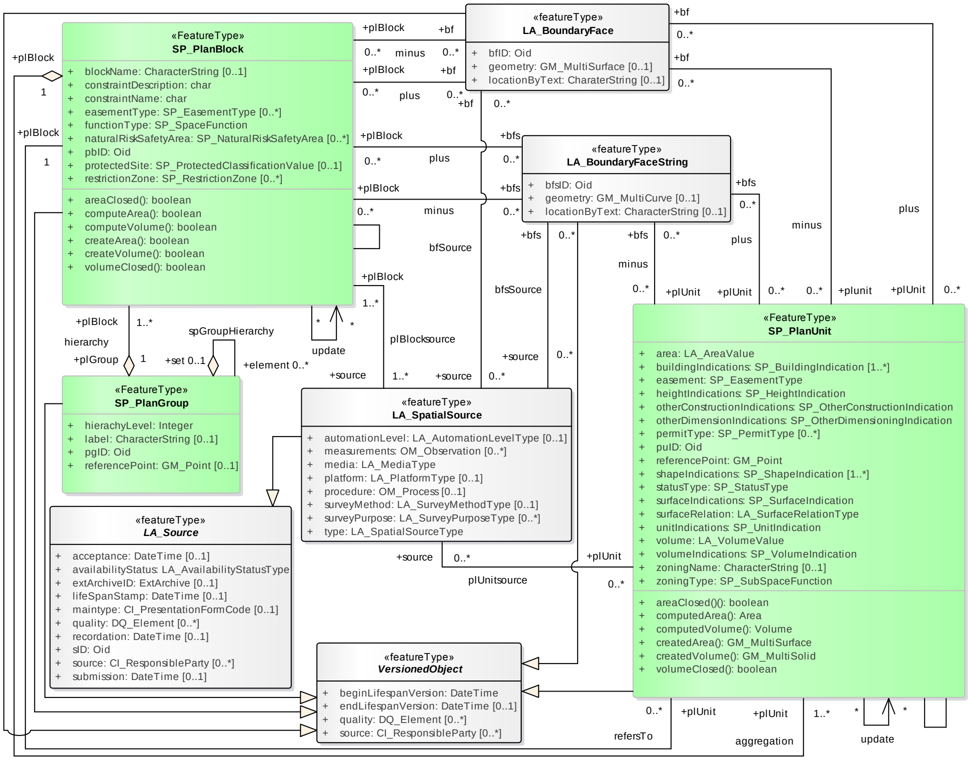


Figure 4-9. Geometry and temporal dimension in Spatial Plan Information.

4.4 Discussion

The Geo-ICT's rapid advancement creates opportunities in land administration and spatial planning to provide integrated and interoperable land-related information to broader stakeholder groups. The LAS shares the same objective as the SII in facilitating land-related information sharing. In most cases, the nature of both land administration and spatial planning involves various parties, inter-related roles, and a variety of spatial information. As both land administration and spatial planning impose RRRs on the same land parcel, their integration in a single domain standard creates a straightforward implementation model of both processes. By the development of classes in spatial plan information package as an attempt to enable a 4D (3D+time) representation of spatial plan and zoning plan (Figure 4-10), we incorporate two considerations for maintaining the completeness and preserving usability for land administration and spatial planning: interoperability and capability to represent RRRs at a sub-parcel level.

4.4.1 Interoperability

Harmonization and standardization are believed to leverage the level of interoperability and reusability of land-related information. Consequently, there is a need to standardize this type of information to provide comprehensive and understandable land-related information to broader stakeholder groups, particularly for specialists and experts in developing land administration and spatial planning systems. ISO 19118: 2011 specifies interoperability as the "*capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units*." The local government can develop LAS on a common platform by ensuring information interoperability between four land management functions (land tenure, land valuation, land-use planning, and land development planning). This arrangement leverages LAS to support more purposes while maintaining the quality of service and security for all stakeholders.

4.4.2 Presenting RRR into sub parcels view

Most sectoral spatial planning policies are applied to a specific jurisdiction area to control intervention in social or physical development, from country to land parcel (Nadin 2007). As LAS's fundamental element, the land registry database provides an administrative boundary for land administration and spatial planning purposes. A sub-parcel division could be crucial to represent more realistic RRRs resulting from sectoral policy integration (Verbeeck et al. 2011 and Inan et al. 2010). Therefore, it is necessary to allow a sub-parcel division for better representing and visualizing spatial planning and land administration integration. A3D visualization of spatial planning helps planners and citizens provide optimal information and insight, especially in dense urban areas involving multiple uses of space (Van Oosterom 2013 and Ahmed & Sekar 2015). Based on the work of Bydlosz et al. (2018) on a 3D Cadastral model for spatial planning objects, our proposal allows a 3D representation in sub-parcel based on zoning plan regulation and delivering RRRs from spatial planning into a land parcel. We consider that the sub-parcel information is better not stored but derived "*on-the-fly*" as an interface object. This arrangement will ensure information integrity in database management by data custodians.

An interface object is a subset of an interface in software development (Puerta 1997) but can reference each other in a specific way. Figure 4-10 shows that spatial planning has different spatial representations for RRRs in a land parcel. Further, a sub-parcel unit may also represent RRRs for vertical urban space, such as strata title. The proposed spatial plan information package is associated with *LA_SpatialUnit*, a class providing spatial representation for sub-parcel. The *LA_SpatialUnit* has a relationship with *LA_BAUnit*, *SP_PlanUnit*, and *LA_RRR*. With this arrangement, RRRs derived from the spatial planning process can be contained in *LA_RRR* through *SP_PlanUnit* and *SP_PlanBlock*.

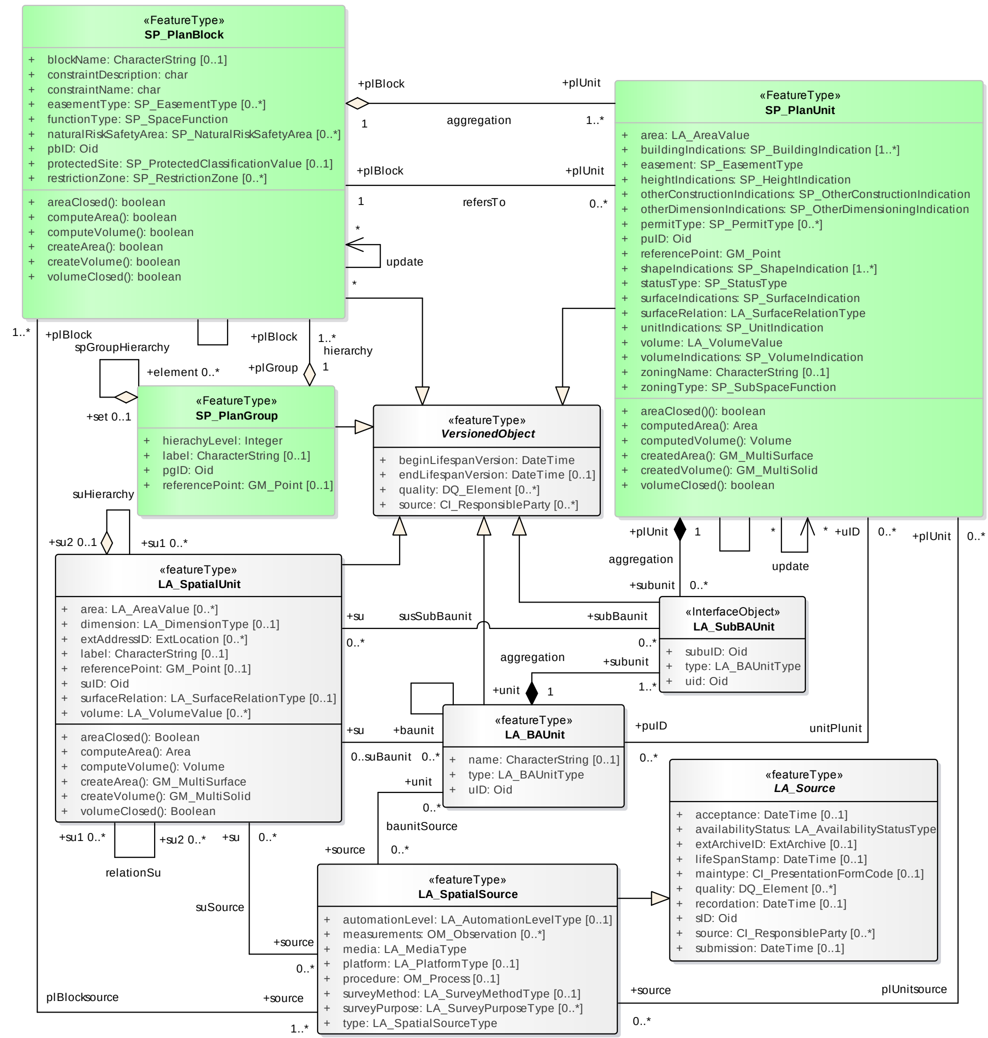


Figure 4-10. Classes in spatial plan information package and their relationship. *LA_SpatialUnit* class and *VersionedObject* class to construct 4D (3D+time) urban planning.

4.4.3 Developing country profile for the LADM using Spatial Planning Information Package: Indonesian cities

To assess the proposed Spatial Plan Information Package (SP Information Package), we implemented its use in developing the LADM profile for a country in a real-world situation. In Indonesia's case, we found that the package can enrich the quality of RRRs by adding restrictions and responsibility derived from spatial planning processes. It is also of national interest for a country to develop and maintain LAS capable of recording, managing, and publishing RRR for all citizens. Current leadership and government institutions recognize the importance of spatial planning and land administration for national and SDG agendas (Abidin 2017). Indonesia's interpretation of the LADM has been constructed in Annex D of ISO 19152:2012 document. In the first model developed by Ary Sucaya (2009), the Indonesian country profile has incomplete RRR information caused by excluding Restrictions (*LA_Restriction*) and Responsibilities (*LA_Responsibilities*). Separate laws and exclusion of relevant authorities in land administration and spatial planning were the reason for this incompleteness of RRRs.

4.5 Conclusion and Recommendation

This chapter proposes integrating the Rights, Restrictions, and Responsibilities (RRRs) information from the spatial plan information, as an additional package, into the ISO 19152:2012 – Geographic Information – Land Administration Domain Model (LADM) standard. Spatial planning plays an essential role in land management. The integration of physical and sectoral planning at the local level usually produces some degree of permissions, authorizations, restrictions, obligations, and sanctions. However, it is typical in many countries to establish land administration and the spatial plan processes through different regulations, authorities, and processes. Integrating spatial plans into a package in the LADM is essential to ensure that stakeholders have the complete picture of RRRs of land or space. The standard development approach was selected so that our model represents and documents the complete view of RRRs from land administration and the spatial planning process is. Through the data modeling process, it can be concluded that the LADM can accommodate a standardized zoning plan and correlate it with the land administration classes to develop the country profile. The zoning objects resulting from a spatial planning process are presented in three classes: *SP_PlanUnit*, *SP_PlanBlock*, and *SP_PlanGroup*. The developed spatial plan information package was successfully applied to the Indonesian the LADM country profile. Therefore, our research is the first to suggest that it is appropriate to include these classes into a package in the LADM to better represent RRRs, particularly in countries that arrange spatial planning and land administration information in separate processes.

Our approach can reconstruct restrictions and responsibilities derived from the spatial planning process and sectoral integration on a specific land parcel or space (2D and 3D) using the SP Information Package classes. However, we realize that spatial planning has many interpretations and variations in many countries. Our work could not cover all aspects representing spatial plan into the land administration. Continuation of research is recommended which focus on these areas:

- Study on 4D (3D+time) spatial plan to represent the spatial planning object's dynamism following the update by the local government.

- Investigation on disaggregation of RRRs in the sub-parcel division since the zoning plan may not share the same boundaries as the cadastral boundaries.
- Development of 3D spatial plan database in city SII.
- Implementation of Spatial Plan Information Package in the permit system and urban plan monitoring.

5

Open Information Sharing To Support PUPM In Indonesian Smart Cities[3]

Digital transformation is a critical factor in localizing Sustainable Development Goals (SDGs) for Indonesian cities. Cities require a reliable and open spatial information infrastructure to monitor and evaluate the success of their implementation of urban plans towards sustainable development. Jakarta and Bandung modernize their spatial data management of their Spatial Information Infrastructure (SII) to support these goals. The One Data Policy, as the national data governance, encourages good data management, transparency, citizens' participation, and innovations. This policy aims to improve data governance and enable local knowledge into national and local governance. This chapter aims to design a policy model for the Open SII at the city level with open participation (or two-way information flows) and accommodate digital twin to reference urban information. Section 5.1 provides the context of the Open SII at the city level. Section 5.2 presents the methodology used in this study. The SII concept at the city level is described in Section 5.3. Section 5.4 contains the Integrated Geospatial Information Framework initiated by the United Nations. The Open SII for smart cities is discussed in Section 5.5. The following section focus on the development of criteria for establishing the Open SII at the city level. The last section contains the conclusion and recommendation.

5.1 Introduction

The UN has identified cities as the key stakeholders of the 2030 agenda for sustainable development (UN-Habitat 2017). In 2007, the total population in cities surpassed the countryside (UN-DESA 2019). Cities are the engine of economic growth and contribute to most of the world's Gross Domestic Product (GDP) (Acuto et al. 2018 and Ringenson et al. 2017). The World Bank (2020) accounted for 80% of the world's GDP in cities to illustrate the magnitude of strain from increasing activities in urban areas. The incoming capital is stimulating land-use change, pressing to essential services, and inviting urbanization into limited urban areas (Bloom et al., 2008 & Colenbrander, 2016). The former the United Nations Secretary-General (2012), Mr. Ban-Ki-Moon, stated that the

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[3] This chapter is partly based on the published a book chapter (Indrajit 2018) and three conference papers (Indrajit et al. 2018, Indrajit et al. 2019 and Indrajit et al. 2020b)

success of Sustainable Development Goals (SDGs) would be determined in cities worldwide. Localization of SDGs and ensuring cities to achieve SDGs indicators have never been more critical than now.

The New Urban Agenda recommends that cities adopt SDGs in urban policies and urban plans. The need for a reliable information ecosystem for cities to support sustainable development in limited urban space is undeniable and unavoidable. UN-GGIM (2019a) recommends the Integrated Geospatial Information Framework (IGIF) to the UN members to efficiently use spatial information by all countries to effectively measure, monitor, and achieve sustainable development at national and sub-national levels. Cities acquire Big Data systems, Information Communication and Technology (ICT), ubiquitous technology, and social media to develop urban intelligence (Nyerges & Jankowski 2009 and Foth et al. 2011) and achieve the vision of a smart city (Batty et al. 2012 and Roche 2014). Batty (2018) recently highlights the importance of the digital twin, a digital mirror image of physical objects and city activities. The mirror image requires information infrastructure to support updating systems to assess the implementation of the urban plan. However, instead of optimizing the existing information infrastructure, such as Spatial Information Infrastructure (SII), or often called Spatial Data Infrastructure (SDI), cities tend to build separate data infrastructure for smart cities (Lea & Blackstock 2012, Pflügler 2016, and Barns 2018). In contrast, many cities in the middle or low Gross National Income (GNI) countries are still struggling to improve their basic capabilities (financial, technology, and human resources) to obtain sufficient urban information for achieving indicators stated in SDGs. Making the SII works for cities, even more in smart cities, is essential for facilitating spatial data sharing and establishing a spatially enabled society (Williamson et al. 2010), which is crucial for the smart city (Roche & Rajabifard 2012). This chapter discusses the improvement of the existing SII to monitor and evaluate urban plans towards SDGs and smart city initiatives in Indonesian cities.

5.2 Methodology

Urban intelligence facilitates all stakeholders to actively share information and knowledge within an information ecosystem, such as SII. Countries establish SIIs based on the belief that they can better facilitate stakeholders in acquiring, managing, and disseminating spatial information parties. Van Loenen (2006) provides six universal components of the SII that are also valid for the city level: policy, standards, technology, institutional framework, financial resources, and human resources. These inter-related components are helpful to establish the Open SII that includes broader stakeholders with more transparency and interactivity. According to Sein et al. (2011), ADR can generate prescriptive design knowledge in innovation, Information and Communication Technology (ICT), and institutional framework artifacts within the organizational setting. This chapter presents ADR for gaining knowledge for developing and evaluating the

Open SII based on the fact that it is under development in Indonesian cities such as Jakarta and Bandung City.

5.3 Spatial Information Infrastructure at the city level

Cities establish and maintain their information infrastructure to secure reliable and continuous data streams to build urban intelligence capability. High-quality spatial information is vital to support evidence-based decision-making in cities, mainly in developing strategy (Batty 2012), monitoring and evaluation (Indrajit et al. 2019), and in operational stages in participatory decision-making (Jankowski & Nyerges 2001, 76-78). In supporting the decision-making process, urban intelligence uses data model integrations, tools, and algorithms to predict future scenarios (Batty 2012). Nyerges & Jankowski (2009) refer to decision support as "*the tools and information provided by or to people during all aspects of their decision-making processes*." They specify the role of spatial information in operational decision-making into five activities: planning, programming, implementation, monitoring, and evaluation (Table 5-1). Garcia Alvarez et al. (2019) propose event-driven processing for decision support systems into five steps: sensing, event definition, detection, reporting, and acting (Figure 5-1). The quality of decision-making in all steps requires reliable access to spatial information. This chapter views these steps as the operational activities that spatial information sharing is used for urban intelligence in city activities.

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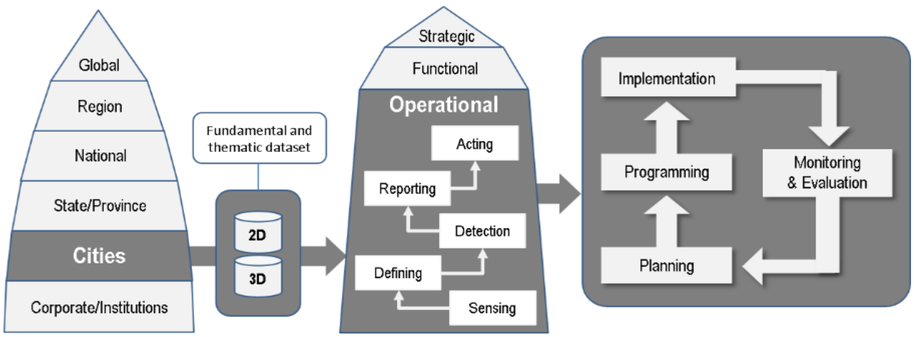


Figure 5-1. The organizational aspect of the SII and its utilization in decision support (Nyerges & Jankowski 2009, Garcia Alvarez et al. 2019; and Rajabifard & Williamson 2001)

Spatial data sharing can be implemented in each of the political-administrative hierarchies, from the corporate level (lowest) to the global level (highest) (Rajabifard & Williamson 2001). This hierarchy is in parallel to the spatial planning and administrative levels (see Figure 5-1). The upper level provides the SII core elements (institutional frameworks, policy, standards, and access networks) and reference datasets for the lower levels to share spatial information. Countries initially adopted the SII concept to facilitate spatial data sharing within government entities (Rajabifard & Williamson 2001). Onsrud et al. (2004) define the SII as "*an institutional concept being advanced to respond better to needs for spatially referenced information in various problem-solving domains*." Arriving at this definition, the SII typical will consist of mechanisms that facilitate data collection, data management, dissemination, and use of spatial information for all parties (Van Loenen, 2006). SII, as a concept, is evolving. The first two SII generations were data-centric and process-oriented with government domination (Masser et al. 2008 and Harvey & Tulloch 2006). The third generation allows co-production, sharing, integration with various data types, and reusing spatial information (Nedović-Budić et al. 2004, Budhathoki et al. 2008, and Hennig & Belgui 2011). Improving the quality of decisions impacting humans and the environment can be achieved through higher resolution and dimensions (Kuhn 2005). The use of 3D city models as digital twins aims to provide a more realistic view of the complex setting of a city and real-time urban dynamics (Batty 2012). According to Pietsch (2000), 3D city models include buildings, vegetation, transportation, and other physical objects. The 3D representation can be used to contain information about Rights, Restrictions, and Responsibilities (RRRs) on urban objects for documenting and visualization urban plans (Indrajit et al. 2020a).

Table 5-1 The simple model of decision support activities in cities.

Activities	Description
1. Planning	"*a look forward to address external influences of human activity at broad spatial and temporal scales.*" (Nyerges & Jankowski 2010)
2. Programming	"*a collection of projects, with each project having associated benefits and costs—but not necessarily expressed in monetary terms.*" (Nyerges & Jankowski 2010)
3. Implementation	"*a detailed economic and social, and environmental assessment is performed.*" (Nyerges & Jankowski 2010)
4. Monitoring	"*the systematic documentation of aspect of program performance that is indicative of whether the program is functioning as intended or according to some appropriate standard.*" (Rossi et al. 2018)
5. Evaluation	"*the systematic assessment of the operational and outcomes of a program or policy, compared to a set of explicit or implicit standards, as a means of contributing to the improvements.*" Weiss (1998)

5.4 Integrated Geospatial Information Framework (IGIF)

UN-GGIM released the Integrated Geospatial Information Framework (IGIF) guideline to the UN member countries into three parts and nine pathways (UN-GGIM 2019a). Part 1 contains the context, vision, and principles of IGIF with predefined goals and strategic pathways for policymakers establishing spatial information infrastructure. Part 2 provides specific guidance and actions that should be taken to implement IGIF. The last part, Part

3, is planned to include templates and operational guidelines to implement the IGIF at national and sub-national levels. IGIF aims to provide guidelines for a country to develop specific action plans to integrate geospatial information management into digital transformation and support evidence-based decision-making (UN-GGIM 2018). The IGIF acknowledges open data and open participation by promoting transparency, collaboration, and cooperation as underpinning principles for the information ecosystem, such as the SIIs (See Table 5-2). Pathways 1 (Governance and Institutions) encourages collaboration, interoperability, consolidation, and integration across many existing platforms. IGIF has similarities with the SII and was initially designed to be used at the national level. from national to small community levels.

Table 5-2 The Underpinning Principles of Integrated Geospatial Information Framework (Source: UNGGIM 2019a)

Principles	Explanation
Strategic Enablement	political and financial supports should be aligned with the government's strategic direction on sustainable development.
Transparent and Accountable	geospatial information is developed and shared with accountability and transparency guidelines so that all citizens, government agencies, academia, and the private sector have access to valuable and underpinning national resources.
Reliable, Accessible, and Easily Used	geospatial information is reliable, accessible, and usable to leverage research and development, stimulate innovation, and support the creation of sustainable services and products.
Collaboration and Cooperation	to perform collaboration and cooperation are factored to strengthen information sharing between providers and users, reduce duplication of effort, make for a robust system, and clarify roles and responsibilities.
Integrative Solution	to be integrative and consider how people, organizations, systems, and legal and policy structures work together to form an effective system for managing geospatial information and its use.
Sustainable and Valued	to enhance national efficiency and productivity; it is sustainable in the long term; and is deployed to provide improved government services to citizens.
Leadership and Commitment	strong leadership and commitment, often at the highest level, enhance geospatial information investments' long-term value.

Both IGIF's strategic pathways and the SII elements proposed by Van Loenen (2006) share seven overlapping aspects. However, IGIF has two additional aspects compared to contemporary the SII concept: (1). partnerships and (2). communication and engagement. As IGIF contains "*general*" guidance, policymakers and national experts in the UN member countries can interpret these principles, goals, and pathways differently (UN-

GGIM 2018, 2019a & 2019b and Scott 2019). UN-GGIM (2019a) prescribes that a geospatially-enabled nation shall share, integrate, and use a wide range of data to achieve sustainable development and recommends seven principles for implementing IGIF and developing and improving the SII at national and sub-national levels (see Table 5-2). There are two critical improvements for spatial data sharing proposed in IGIF. First, IGIF promotes open data and participatory as the guiding principles in its strategic pathway (UN-GGIM 2019a). Second, IGIF is anticipating the current and growing availability of more data types, data sources, and needs are considered in IGIF to reflect on the advancement of ICT. Both technology evolution and the emerging open data ecosystem depend on 'location' and 'integration.' Big data, structured and unstructured data, open data, and other realities are not fully anticipated by the SII concept that relies on authoritativeness and structured spatial data. IGIF will stimulate opportunities to improve the existing SII for linking to these external data to add potential value and services to everyday queries of information for decision-making.

5.5 The Open SII for Smart Cities

A smart society is an essential characteristic of a smart city. Making the society spatially enabled by allowing citizens to access and contribute information is essential for making a city smarter (Williamson et al. 2010 and Kitchin 2014a). A smart city itself is an open data generator for its citizens. Cities are considered suitable for implementing SII for their capacity to establish a supportive environment for spatial data sharing and co-production (Castelnovo 2016 and Nedović-Budić et al. 2004). The more open data available, the more citizens will participate (Kavanaugh et al. 2009 and Mellouli et al. 2011). The higher the quality of data contributed from the community (Brovelli et al. 2016 and Zuiderwijk et al. 2014).

5.5.1 Definition of Open SII

The vision and actions to integrate open data and open participation in a city should be found in the form of policy, policy value, behavior, action plans, and resource management. Vancauwenberghe & Van Loenen (2017) propose open data principles as the core value of Open SII. They regard policy-makers and informed leaders as the key driving forces in providing open access and facilitating stakeholders to contribute spatial data. For consistency, this study defines the Open SII as: "*a collaborative framework continuously facilitating the efficient and effective generation, dissemination, and use and reuse of needed geographic information to all stakeholders capable of applying open data principles and open participation.*"

5.5.2 Principles in Open SII

The societal benefit of spatial information can be sourced from innovative uses of the spatial data content exchanged among broader stakeholders. At the 46th Session of the UN Statistical Commission and Countries affirmed that more robust open data ecosystems would improve decision-making (SDSN 2015). Open data gains more interest in cities worldwide and is often associated with many success stories in cities, notably supporting humanitarian efforts (Grus et al. 2008) and urban mobility (Harvey & Tulloch 2006). The Open Definition 2.1 characterizes "*open*" as allowing "anyone can freely access, use, modify, and share for any purpose" through open works and open licenses (Open Knowledge Foundation 2017). The G20 working group defined six Open Data principles: open by default, timely and comprehensive, accessible and usable, comparable and interoperable, improved governance and citizen engagement, and inclusive development and innovations (OECD 2017). In developing the Open SII principles, this study adopts the definition of open data for relevant spatial information, including high-value and high-resolution datasets.

In 2014, academia proposed FAIR (an abbreviation of Findable, Accessible, Interoperable, and Reusable) guiding data principles to be the minimum requirement practices to improve discovery, access, integration, and re-use of scientific materials (Wilkinson et al. 2016). The FAIR guiding principles acknowledge the importance of standardization and interoperability to make open data "*machine-readable*" and "*machine-actionable*" for better discovery and reuse. Information interoperability will automatize the process without or minimal human intervention to identify the type of object, evaluate metadata and data elements, assess the usefulness within the context and its usability (licensing, accessibility, or constraints), and take meaningful actions. It is worth noting that the FAIR guiding data principles are not necessarily open, wherein "*Accessible*" still allows contributors to not disclose data and services from public access due to privacy or security, or competitiveness (Mons et al. 2017). Innovations in the Geo-ICT gave birth to "*NeoGeographer*," a new wave of spatial data contributors (Goodchild 2009 and Hudson-Smith et al. 2009). This wave shifts the producer-user roles in the next-generation SII (Budhathoki et al. 2008). Further, Volunteered Geographic Information (VGI) has proven its potential to produce spatial information at a scale of 1:10,000 (Olteanu-Raimond et al. 2017). At this quality, VGI is promising and can be considered to be an alternative solution for closing data gaps and the source of updating the base map in urban and built-up areas (McDougall 2009). Seeger (2008) classifies the "*facilitated VGI*" (f-VGI) as a variant of VGI based on the roles of facilitator, predefined criteria, and process. A typical f-VGI provides user interfaces for individuals or groups to contribute their Local Spatial Knowledge (LSK) and present it on a specific map (Minang & McCall 2006). However, most VGI initiatives rely on access to georeferenced spatial information produced by government institutions (Minang & McCall 2006 and McDougal 2009). Therefore, the Open SII will facilitate government institutions to disseminate high-quality open government data to society and enable the society to contribute spatial information. These capabilities are necessary for participatory urban plan monitoring and making cities smarter. Consequently, the role of local governments may gradually shift from executor to facilitator role in Open SII.

5.5.3 Data sharing mechanism in Open SII

Information flows between stakeholders should be carefully designed and managed to ensure successful participatory activities. This study considers the quality of the information flows concept proposed by Gudowsky & Berthold (2013) for developing the Open SII mechanism. The quality of information flows concept is distinguished into *one-way* and *two-ways*, depending on the recipient's understanding, media, and timing of the data. The *one-way* flow covers two types: *uni-directional* and *bi-directional. Uni-directional* is the most commonly used in sharing the map with no right for citizens to negotiate, while the *bi-directional* flow is two reciprocal *uni-directional* flows. Open participation requires *two-ways* flows where the transfer of information has more intensity between stakeholders in *discussion* and *dialog* types (Gudowsky & Berthold 2013). *Discussion* requires a consensus from all stakeholders for adopting spatial information. *Dialog* enables stakeholders to experience the free flow of information without a consensus in improving understanding of the specific topic. Since the early development of the SII concept, data quality has been acknowledged as an essential aspect (Goodchild 2007). Like contemporary SIIs, the Open SII shall maintain a spatial data catalogue and metadata for each data shared from the ecosystem. The facilitator of the Open SII shall provide a mechanism, specific roles (e.g., validator), or tools for assessing the quality of each spatial information managed and shared in the system. Contributors must submit data and metadata, including quality information and how data is obtained (Figure 5-2).

Users can examine the quality of information from metadata provided in Open SII. A validation and verification mechanism shall be developed and performed as it will affect the use of spatial information for decision-making. The value of spatial information depends on its usage (Onsrud & Rushton 1996, NRC 2006, p. 47, and Crompvoets et al. 2010). The Open SII aims to maximize the benefit of digital transformation by providing open information infrastructure that enables broader stakeholders' to interact fully and contribute spatial information into the city's databases with user-friendly devices and quality assessment mechanisms. Coleman et al. (2009) classify users based on motivation, education, and experience, while Munar (2000) includes the end-user class to represent non-traditional producers (i.e., citizens, planners, policy- and decision-makers) (see Table 5-3). End-user is an individual or a group of individuals who use spatial data but have no interest in contributing. Although sometimes, they have the knowledge and skills to produce spatial data but do not have motive, time, or hindered by an obligation or ethics to share their spatial data.

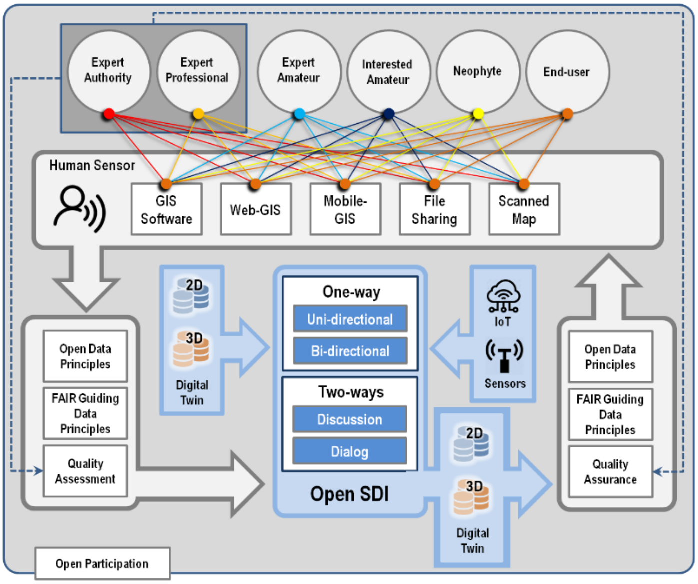


Figure 5-2. Mechanism of Open SII.

Table 5-3 Type of stakeholders in a participatory environment (Source: Coleman et al. 2009 and Munar, 2010).

Contributors	Description
Expert Authority (EAUTH)	Individuals or a group of individuals who have educational backgrounds and experiences in producing high-quality spatial data. EAUTH should be capable of assessing the quality of spatial data in a networked environment. EAUTH can be held accountable for the success of the whole system.
Expert Professional (EPRO)	Individuals or a group of individuals who have the job of producing high-quality spatial data with related educational backgrounds and experiences. This person is responsible for any claim related to the quality of the product.
Expert Amateur (EAMT)	Individuals or groups of individuals who contribute their spatial data with knowledge and skills sometimes have related educational backgrounds. EAMT performs passionately in producing spatial data but has no economic benefit intention.
Interested Amateur (IAMT)	Individuals or groups of individuals contribute their spatial data with minimal knowledge and skills but actively consult the expert to produce spatial data. IAMT is passionately performing the job, learning, and gaining experiences.
Neophyte (NEO)	Individuals or a group of individuals who contribute their spatial data with no knowledge and skills but having the passion, time, and motivation.
End-user (EUSR)	Individuals or a group of individuals who are only use spatial data. Sometimes, EUSR has the knowledge and skills to produce spatial data but do not have motivation, time, or hindered by other obligation or ethics to share their spatial data.

5.5.4 The Open SII and smart cities

Local governments will be the prominent producers and custodians of digital twins and other urban information. It will also be valid in the Open SII. The increasing demands of open spatial data representing urban features and human activities in higher resolution, multidimensional, and real-time will allow more analytical and simulation capabilities (Nyerges & Jankowski 2009 and Batty 2012). As for monitoring changing landscape and urban environment efficiently, the Open SII should maintain the mainstream of "*collect once, use many times*" and practice good spatial data management. This principle is used in many countries by developing a "*non-rivalrous*" policy for National Mapping Agencies (NMAs) in producing spatial reference data (i.e., topographic maps and cadastre maps) (Lauriault 2017). Transforming the SII to the Open SII requires a set of policies to guide authorities in consolidating their resources and actions needed for implementing open data and open participation. Legal frameworks may be the best option to avoid policy incoherencies that may arise in the ever-changing political sphere to anticipate a disruption in technology (Kitchin 2014b) and societal demands. Legal frameworks should cover three aspects: (1). provision of access in open (spatial) data sharing; (2). enablement of use and re-use; (3). organization of data sharing (Janssen 2008); and two-way information flow to enable data contribution from all stakeholders, including local citizens (Gudowsky & Bechtold 2013).

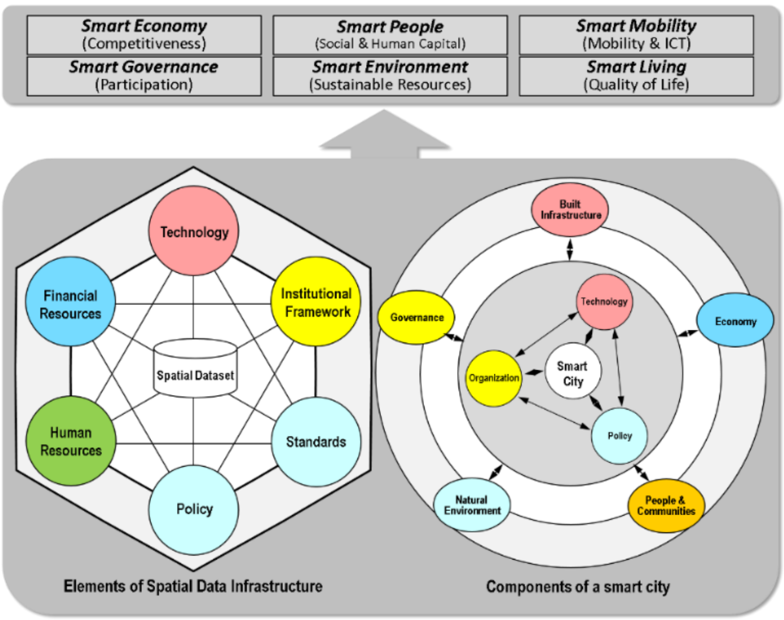


Figure 5-3. The SII elements and components of smart city function. (Van Loenen 2006, Batty et al. 2012 and Chourabi et al. 2012).

The legal frameworks can strengthen the Open SII in a way that minimizes unpredictability, multiple interpretations and enable citizens and non-government actors to be involved in policy- and decision-making. In the technical aspect, legal frameworks are necessary to ensure interoperability and comparability of data and the safeguarding process to reuse open spatial data (Vancauwenberghe & Van Loenen 2017). Giffinger et al. (2007) advocate that a city's smartness must cover at least six aspects: economy, people, governance, mobility, environment, and living. Chourabi et al. (2012) propose three core components of the smart city framework (Policy, Organization, and Technology) (see Figure 5-3). In response to the smart city concept, Kuhn (2012) argues that smart cities should have ten geospatial intelligences: location, field, object, network, process, resolution, accuracy, semantics, value, and also-rans (nearness, features, layers, motions, paths, uncertainty, and scale). Geospatial intelligence is sourced from the government-maintained database and can be sourced from real-time sensors, participative mappings, tools, and analytical modeling. A smart and sustainable city operates based on accessible, up-to-date information.

5.6 Criteria for the Open SII for Indonesian Smart City

Jakarta and Bandung were among the first self-declared smart cities. Since 2012, local governments in these two cities are investing heavily in ICT, Big Data, and IoT. From interviews held in 2017 and 2019, we found that these investments were initially driven by a massive push from global trends but were unattached from the existing SDI activities. These cities planned their smart city solely based on its function, not the components. When these cities built their smart city systems, policymakers and planners faced many interpretations of smart cities and ICT vendors. In the national arena, *Bappenas* (2018) prescribes "*smart*" to obtain "*livable*," "*green,*" and "*competitive cities*."

In early 2017, the Government of Indonesia (GOI), through the Ministry of Communication and Information (MOCI) (2017), launched the "*Towards 100 smart cities*" as a national initiative for cities to accelerate and improve public services, harness innovation in solving priority problems and build competitiveness based on an integrated data and collaboration between sectors. This initiative is expecting to construct a smart society and smart nations in the longer term. Geospatial Information (GI) Agency has been promoting geospatial information and the SII to integrate into the smart Indonesian cities. Many policies were being made towards data-driven policymaking in the past five years, with smart city initiatives dominating government and society spheres. This section presents the adoption of IGIF strategic pathways for developing criteria for the Open SII at the city level (Table 5-4).

Table 5-4 The criteria in establishing the Open SII at the city level

IGIF Strategic Pathways	Criteria	The main question addressed
Governance & Institutions Financial Capacity & Education	*(1). Leadership, Data Governance, and Sustainable Financial and Human Resources*	Has the city secured an adequate financial budget and human resources in allowing sustainable spatial data sharing for all stakeholders?
Legal and Policy Partnerships Communication & Engagements	*(2). Institutional Arrangements for Open Data and Open Participation principles*	Do authorities provide and implement supportive leadership and policy to ensure data findability, share complete data as open by default with timeliness, citizen engagements, and inclusive innovation, and allow consensus-building and collaboration in producing spatial data?
Data	*(3). Digital twin at sufficient quality*	Does the city provide spatial data (both 2D and 3D) with a sufficient level of detail and quality as open data to represent physical and non-physical characteristics and be used as Common Operating Map?
Standards	*(4). Information interoperability*	Does the city comply with international and national standards in spatial data sharing and contribution for guaranteeing interoperability and comparability, particularly in allowing machine-readable and machine-actionable in finding and reusing spatial data?
Innovation	*(5). Fit for Purpose Technology*	Does the city provide 'fit for purpose' facilitation to enable data sharing, co-creation, and reuse of spatial data for its stakeholders, mainly urban dwellers?

5.6.1 Criterion 1: Leadership, Data Governance, and Sustainable Financial and Human Resources

This criterion focuses on data leadership, data governance, and sustainable financial and human resources. Governance, leadership, and human resources are critical in establishing the SII (Van Loenen 2006). Good leadership with sufficient political support will carry the vision of communication and coordination in the SII development (Stagars 2016). Indonesia is fortunate to be led by three consecutive presidents in favor of establishing a sustainable SII. They were fully aware of the importance of citizens having spatial data literacy. The current administration is trying to comply with UN-GGIM recommendations in establishing capacity-building programs, both in formal education institutions and training courses, to ensure sustainability in management and entrepreneurship in geospatial information (Hadley & Agius 2019). The Government of Indonesia (GOI) continuously improves its spatial data ecosystem through policy-making and policy integration on spatial data sharing since 1991 (Lilywati 2007 and Indrajit 2018). Geospatial Information (GI) Act was enacted in 2011, provide explicit instruction to the government to establish national and local SIIs. GOI launched the One Map (OM) Policy for promoting spatial information for national economic development. This policy was included in the 8th of Economic Stimulus Package Policy in 2016 (Ministry of Foreign Affairs 2015) to solve boundary conflicts and overlaps in land utilization permits and enforce the implementation of urban plans. To improve spatial data sharing, the National SII Network improved in 2014 to better address data governance, accommodate more stakeholders to access, and contribute spatial information. The National SII Network regulation allows citizens (as individuals or members of the group) to access and contribute spatial information to the SII.

This setting made a case for establishing Open SII, and the authorities are now making the necessary improvements, mainly in practical and technical aspects and citizens' engagements. Consequently, countries and cities should allocate sustainable funding and resources for establishing and maintaining SII. Sustainable funding for spatial data sharing is demanded explicitly in Indonesia's laws, most notably in the GI Act and Local Government Act (2014). These laws also specify the type and specification of spatial data funded by the public budget and instructions to establish data infrastructure. Starting from 2015, GI Agency, the nation's flag carrier for geospatial information administration, joined the national economic cabinet team under the Ministry of National Development Planning (*Bappenas* 2016). This institution arrangement is necessary to make the availability and accessibility of spatial data at the center of national policy- and decision-making and make better integration of spatial and statistics information. Like the World Bank, GOI also includes the SII into essential infrastructure (i.e., road, railways, and dam) that a country should develop and maintain. In the National Development Plan 2020-2024, *Bappenas* recommends three possible alternative sources for financing infrastructure development (including SII). They are Public-Private Partnerships (PPP), Non-Government Investment Financing (*Pembiayaan Investasi Non-Anggaran pemerintah*/PINA), and *Sukuk* (an Islamic financial bond that complies with Islamic religious law) (*Bappenas* 2019). Although access to spatial information has been improved and the Ministry of Education is equipped with 20% of the national budget for primary and higher education (World Bank 2014a), governments still face the challenge of improving spatial intelligence for their citizens (UGM 2013). However, for improving citizens' data literacy, communities in Jakarta and Bandung have organized many engagement events to familiarize the use of open data and IoT. Amhar et al. (2015) projected 50,000 workforces needed in the year 2030 to produce spatial information for 520 cities and municipalities in Indonesia. Since the early 2000s, GI Agency has been implementing a collaborative approach with professional associations and universities in building capacity in geospatial information. GI Agency establishes eighteen research centers and delegating certification processes to these actors (Kusmiyarti et al. 2019). As an active member of the Association of Southeast Asian Nations (ASEAN), Indonesia agreed to include surveying into ASEAN-wide liberalized job marketplace (Teo 2004). For this purpose, Indonesia developed the National Competency Standard in Geospatial Information (*Kerangka Kompetensi Nasional Indonesia*/KKNI), consisting list of requirements, assessment mechanisms, and guidance according to the Mutual Recognition Agreement (MRA) on Surveying Qualification (ISI 2019). This standard covers 260 units of competencies in the subfield of Terrestrial Surveys, Hydrographic Surveys and Mapping, Photogrammetric Surveys and Mappings, Remote Sensing, GIS, Cartography, and Thematic Surveys. Indonesia welcomes qualified professionals from ASEAN countries who are allowed to work in surveying and geomatics.

From the interviews held in 2019, we found that only three smart cities accommodate geospatial information into their smart city master plan (Jakarta, Bandung, and Bogor). They are still room for improvements in their geospatial technology aspects. All interviewees agreed that the absence of spatial information at higher resolution and dimension was one of the obstacles in making their city smarter and sustainable. In mid-2019, the One Data Indonesia (ODI) regulation was enacted to ensure availability, quality, integrity, accessibility data for planning, implementation, evaluation, and development control essential for supporting the SDGs programs in Indonesian cities. Jakarta and Bandung shall follow the organization structure provided in ODI regulation at the local level. Under this regulation, a city shall establish the forum one data with six functional roles: C*oordinator*, *Supervising Agency*, *Data Custodians*, *Supporting Data Custodians*, and *Data Producers* (see Figure 5-4). The ODI regulation prescribes public institutions to appoint a unit as data custodian. Data custodians are responsible to collect, examine, and manage data submitted by Data Producers. This regulation also mandate data custodians to disseminate data. Most of the Data and Information Office in the local government don't have adequate staff capable of managing data. Therefore, the ODI regulation allows other agencies to perform the role of Supporting Data Custodian. Local Steering Committee (i.e., Governors and Mayors) are responsible for delivering policy on data provision and data management. At the same time, the Coordinator takes the lead in the organization of forum one data. Offices and units within the city that produce or regularly acquire data as Data Producers role. Local Development Agency is mandated to take the coordinator ODI role and provide adequate funding, facilities, and funding for the secretariat. Office of Communication, Data, and Information will be the only data custodian for the city to provide a single window for data dissemination. Cities may establish an office or unit as supporting data custodians based on their functionality and other circumstances. At the national level, ODI prescribes the establishment of the ODI's National Steering Committees consisting of ministers and heads of the agency (Indrajit 2018 and Indrajit et al. 2020b). This committee is responsible for policymaking, coordinating, monitoring, evaluating, resolving disputes concerning data governance, data provision, encouraging open data and transparency, and supporting the national statistic system.

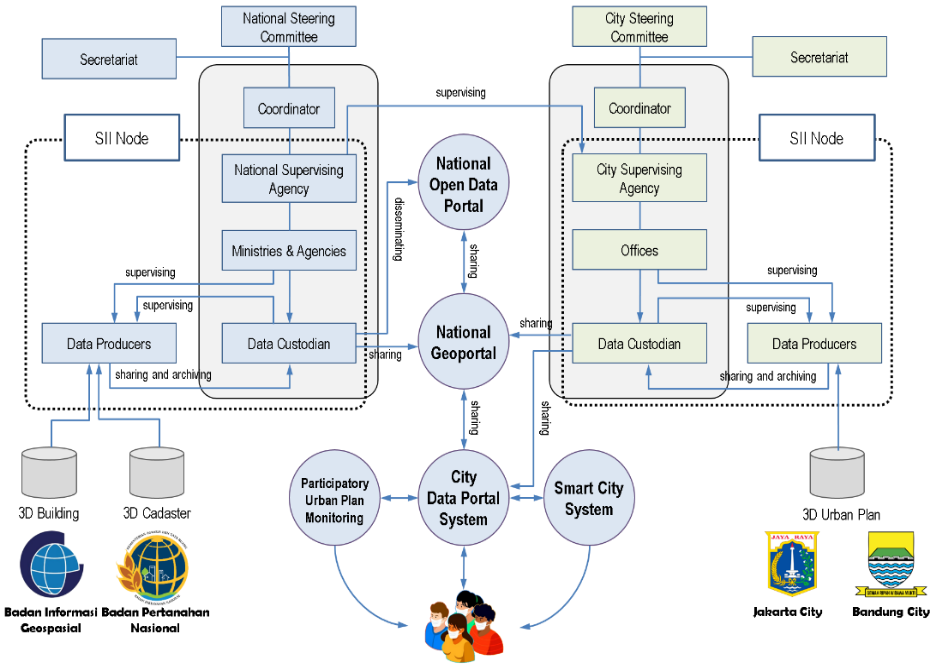


Figure 5-4. Institutional arrangements of One Data Indonesia (Presidential Decree on One Data and Presidential Decree on the National SII Network) (Indrajit et al. 2020b)

Jakarta and Bandung must arrange their institutions and establish a Local Steering Committee consisting of data producers, data custodians, and supporting data custodians. The local steering committee shall be filled with governors or mayors while data producers are from offices and units that produce data. Each local government must have a single data custodian and one or more "*supporting data custodians*." *Bappenas* recommends Local Development Planning Agencies as coordinator and *Pusat Data dan Informasi* (local centers for data and information) as data custodian. In 2018, the Governor of Jakarta decreed "*Jakarta One Integrated Map*" to integrate spatial and statistical data across institutions for supporting priority programs and localization of SDGs. While in Bandung, Mr. Ridwan Kamil, former Mayor of Bandung, initiated data and IT governance within the city's e-government framework for good governance and partnership with the community and the business (Bandung City 2017). He also started establishing Bandung Smart City in 2014, which currently provides almost 400 apps for its citizens. With almost seven years of support from the World Bank, open data initiatives expand across Indonesia (World Bank 2017). Since 2013, the World Wide Web Foundation hosts an annual series of citizen engagements via *HackJakarta* (Stagars 2016), and Bandung has conducted similar events as early as 2011 (Kripe 2011).

5.6.2 Criterion 2: Institutional Arrangements for Open Data and Open Participation principles

The 1945 Constitution mentions the freedom of information that safeguards citizens in obtaining, possessing, storing, contributing, reusing, and disseminating information for their own or social environment development. Public Information Disclosure (PID) Act stimulates a paradigm shift in access to public spatial information in Indonesia by providing a mechanism for classifying, releasing, and accessing public information. This Act establishes the Public Information (PI) Commission responsible for constructing guidelines and dispute resolution and public information mediation. This commission commands data producers to publish public information, perform "*impact testing*" and publish its result to limit or exempt public information publication. Open data and open participation principles have been accommodated in many other laws and regulations such as Disaster Management Act (2007), Local Government Act (2014), Spatial Planning Act (2007), Presidential Decree on the National SII Network (2014), and Presidential Decree on One Data Indonesia (ODI) (2019). The One Data Indonesia policy supports the national and local governments by the ODI regulation to strengthen data management and data sharing within government institutions and local governments (Figure 5-5). The National SII network regulation acknowledges local citizens as data contributors at all levels of SII. These laws and regulations, and policies aim to bind stakeholders' commitment to actively involved, participating, and contributing to spatial data sharing. Therefore, the existing regulations allow local citizens to access and contribute spatial information in urban planning, particularly in monitoring the implementation of urban plans. Geospatial Act and ODI regulation mandate Geospatial Information Agency (GIA) as the leading and supervising institution for spatial information management to establish, connect and maintain Spatial Information Infrastructure at all jurisdiction levels, from national to cities.

The IGIF promotes partnership as a strategic pathway to ensure cross-sector cooperation, coordination, and collaboration between all stakeholders for the national geospatial information framework (UN-GGIM 2017). IGIF should be implemented in National and City level SIIs (see Figure 5-5). However, it has not yet provided a guideline for partnerships at the local levels in sufficient detail where the actual works for achieving SDGs are taking place. The successful implementation of the SDGs depends on their localization, such as collaboration between local governments with local citizens and local businesses in integrating sustainable development indicators into urban planning, project implementation, and monitoring and evaluation. Therefore, partnerships shall provide high-resolution data for the localization of SDGs as the highest priority instead of aggregative data for reporting purposes. Open data is considered a prerequisite for making stakeholders in Indonesian cities participate in spatial data sharing in this configuration. Figure 5-5 shows the relationship among these legislations and policies for establishing the Open SII and connecting it with smart city initiatives for Indonesian cities.

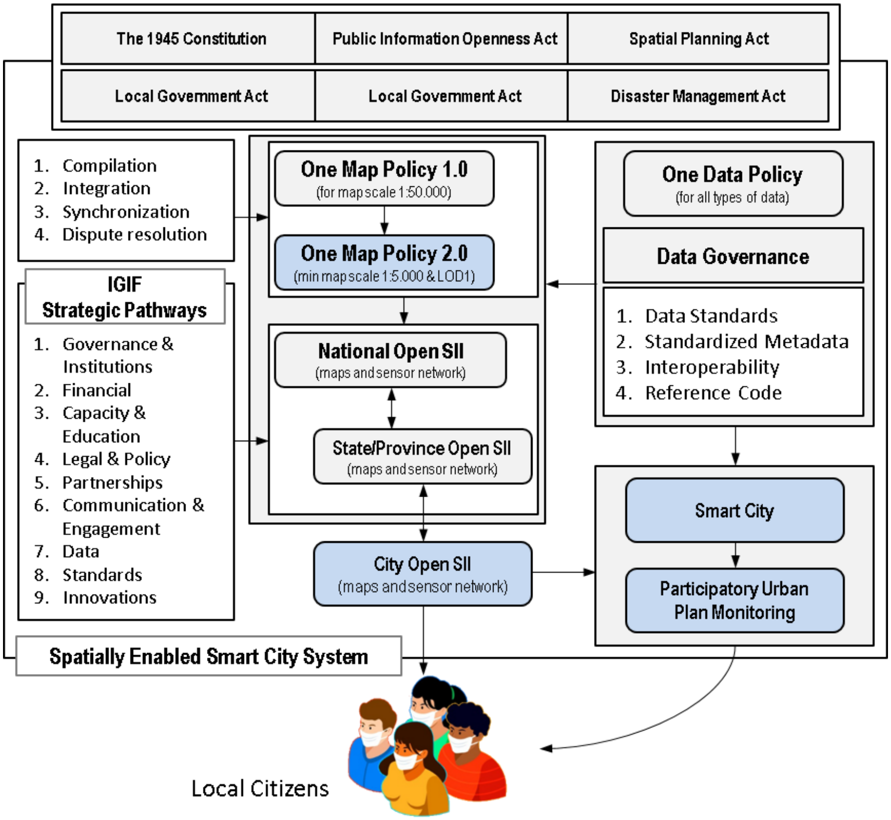


Figure 5-5. One Map Policy and One Data Policy to acknowledge citizens as data contributors

5.6.3 Criterion 3: Digital twin at sufficient quality

The role of high-resolution spatial information is increasingly significant, particularly for adopting SDGs indicators into urban plans. The UN adopted the resolution on strengthening institutional arrangements on spatial information for achieving SDGs (UN-GGIM 2017). The Indonesian government has established special regulations for making the SDGs as a reference to ensure the achievement of sustainable development. All development stages in Indonesia are expected to refer to and synchronize with the SDGs' goals and indicators and then be adopted into the land use designation stipulated in the spatial map and zoning regulations. *Bappenas* (2017) launched the "*Thematic-Holistic-Integrative-Spatial*" (THIS) approach to synchronize development plans, highlighting the need for up-to-date spatial information. The spatial aspect of the "*THIS*" approach is highly dependent on the existence of large-scale topography maps. However, large-scale topography and thematic maps are still limited across cities in Indonesia, hindering the urban planning process, zoning arrangements, and environmental impact analysis (Afriyanie 2020). In Indonesia, Spatial Planning Act and Local Government Act prescribe clearly that policy and decision-making on land management should refer to urban plans, particularly in the utilization and control of land and space for various development activities. Afriyanie (2020) also highlighted the importance of 3D city models at LOD1 for urban planning as they may be contained in topographic maps at scale 1:1,000 and Level of Detail 2 (LOD2). Spatial information in urban planning and SDGs activities is not only for data analysis or reporting purposes but primarily for planning, monitoring, and evaluating plans' implementation (Indrajit et al. 2019). For example, a study for reducing the impact of flooding due to sea-level rise requires large-scale spatial information to represent landscape, drainage, buildings, and public facilities information. Semarang City conducted this analysis to construct a new and improve existing levee as part of its effort to achieve sustainable development (Laeni et al. 2021).

Local government creates and updates spatial information beyond after project completion. Therefore, Indonesia's specification of topographic maps needs to be revised to meet urban planner requirements. For example, it lacks public facilities, utility networks (including pipelines, cables, and sewages), and 3D buildings for smart city and SDGs purposes. Geospatial Act mandates Geospatial Information Agency (GIA) to provide topography maps (coastlines, digital elevation model, water bodies, toponym, administrative boundaries, transportation and utilities, building and public facilities, and land cover) to a scale of 1:1,000. By the year 2019, topographic maps at a scale of 1:1,000 are only available in several cities, such as Jakarta, Bandung, Medan, Surabaya, Palu, and Banyuwangi. It is a considerable gap to fill by governments in providing high-resolution spatial information to support the urban planning process for the localization of SDGs before 2030 (see Table 5-5) (Abidin 2018). Responding to this challenge, the GOI plans to accelerate the large-scale mapping by including it in the national action plan 2020-2024 for the last ten years of SDGs (World Bank 2018).

Table 5-5 Availability of Topographic Map for supporting "*Towards 100 smart cities*." (Source: Abidin 2018).

Map scale	LOD	Demands	Supply	Availability
1:500	LOD 2	100 cities	0 cities	0% (status 2018)
1:1,000	LOD 1	100 cities	5 cities	4% (status 2018)
1:5,000	LOD 0/1	377,824 map sheets	3,922 map sheets	1% (status 2017)

From interviews held in 2019, GIA will produce 3D city models at least to LOD1 and intensify coordination with local governments to accelerate map provision for developing urban plans at scale 1:5,000 and share it with their citizens as public information through national geoportal. Open data initiative in Jakarta and Bandung provides access to the government's data to citizens via an open data portal (data.bandung.go.id and data.jakarta.go.id). As a smart city requires, Jakarta and Bandung find creative solutions to provide their digital twin. The previous study identified that only Jakarta and Bandung had developed 3D city models towards digital twins for their smart city systems (Indrajit et al. 2018 and Indrajit et al. 2020b). This study conducts two surveys (in 2017 and 2019) to the SII stakeholders and map users in Jakarta and Bandung, including central and local governments, urban planners, NGOs, and citizens. The survey revealed that stakeholders are in favor of having access to 3D city models and contributing feedback to the city (Figure 5-6).

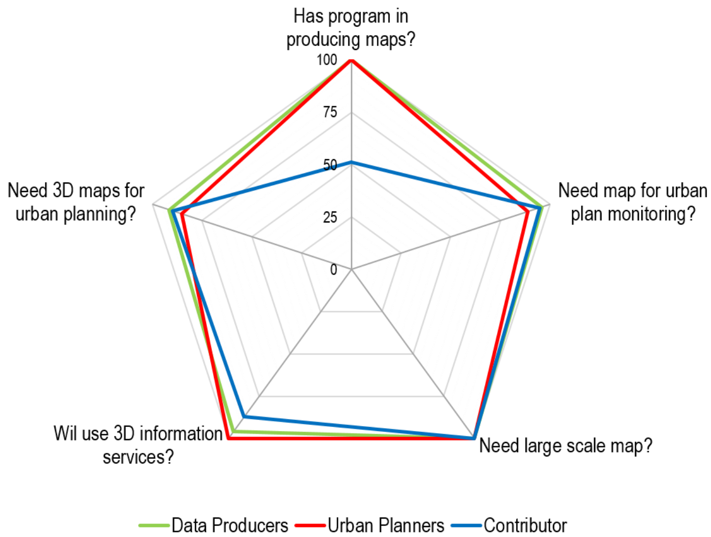


Figure 5-6. Perception of 3D city models among stakeholders in Jakarta and Bandung (surveyed in 2017)

For stakeholder analysis purposes, this study classifies three roles in developing the Open SII at the city level: data producers, urban planners, and data contributors. Data producers are authoritative map producers. Data contributors include VGI and private sectors, which occasionally produce spatial maps needed by a city. From the surveys and interviews held in 2017 and 2019, a consensus from all respondents that a city should have up-to-date large-scale maps and 3D city models with sufficient granularity (at map scale 1:5000 or better) and quality. These respondents express their interest to co-produce spatial information with citizens (see Figure 5-7). However, only a few data producers (and data custodians) provide tools for citizens to produce crowdsourced spatial data. Only half of them conduct spatial data quality checks for data contributed by the citizens.

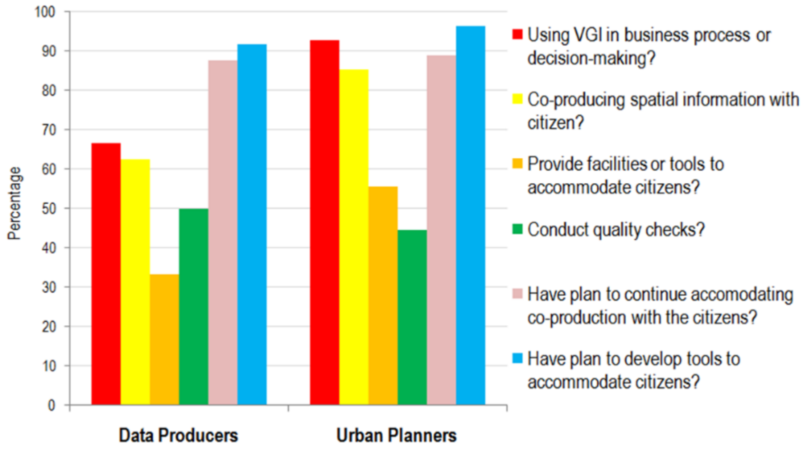


Figure 5-7. Plan for co-producing spatial information in Jakarta and Bandung (surveys conducted in 2017).

5.6.4 Criterion 4: Information interoperability

GI Act, PID Act, the One Map Policy (OMP), and the One Data Indonesia (ODI) regulation are constructing legal frameworks for nationwide spatial data governance (Indrajit 2018). This framework binds data producers to provide maps using a unified geospatial reference, common data models, national standards, and demanding data custodians to publish spatial information funded by the national and local budget to the national geoportal. The ODI regulation explicitly instructs data producers to attach standardized metadata and use a "*machine-readable*" format for every spatial data produced within the government's data ecosystem. This framework is also ensuring interoperability and comparability. Until 2018, there are over ninety national standards on spatial information available for geospatial communities in Indonesia. These standards are sourced from identical or modified International standards published by the International Organization for Standardization (ISO) and self-formulated standards proposed by stakeholders (Silalahi et al. 2018). Jakarta and Bandung apply Indonesia Geographical Features Catalogue (often called *Katalog Unsur Geografi Indonesia* or KUGI) for their spatial database. KUGI was developed by Geospatial Information Agency (BIG) based on ISO 19110:2016 on Geographic information — Methodology for feature cataloging to improve interoperability and ensure fit for purpose to spatial data within the Indonesian SII (Abidin 2018). BIG develop web application to gather inputs from all stakeholders (www.kugi.inasdi.or.id). However, the updated KUGI, version 5, only specifies 2D spatial data themes. The next improvement on KUGI must accommodate 3D spatial representation to support the smart city and participatory urban plan monitoring. From interviews held in 2019, GIA decided that 3D city models will be in the OGC *CityGML* format, but it is unclear whether these cities can make it up-to-date in sufficient detail (LOD3 or LOD4) for smart cities.

OGC anticipates the integration of sensors into smart city systems. Most of today's smart city systems implement four Service-oriented Architecture (SoA) layers (Percivall et al. 2011): Sensing, Data, Business, and Application layers. At the lowest level, the Observation and Measurement (OM) level, OGC issued sensor integration for the SII in smart cities. The OM level contains Sensor Web Enablement (SWE) standards to enable interoperability for developers and industries in benefiting the advancement of pervasive and ubiquitous technologies (Percivall et al. 2015) (see Figure C-1 in Appendix C). The spatial database shall ensure information interoperability for both 2D and 3D urban information. The '*data layers*' accommodate urban information on multiple scales and manage urban information differently from various sources and the semantic 3D city models (see Tables B-1 to B-4 in Annex B). Kolbe (2009) and Kolbe et al. (2013) highlighted the importance of integrating ontological structure, spatial, and graphical aspects into the semantic 3D city models. The data layer facilitates data ingestions, quality assessments, and dissemination. Open standards in establishing the Open SII will construct interoperability for connecting information services with minimal or no cost. OGC publishes the Catalogue Service for the Web (CSW) to facilitate the user in discovering, browsing, and querying metadata and binding spatial information (and metadata) services shared through geoportal (see Figure C-1 in Annex C).

The '*business layer*' contains fundamental business functions of a smart city (Anthopoulos & Fitsilis 2010), such as catalogues and semantics, encodings, catalogue and semantics, visualization and decision support, and analytics and models, as well as access control and maintenance of the systems (Percivall et al. 2015). All layers working within the data and business layer must comply with ISO and OGC standards (see Figure C-1 in Annex C). Its primary function is to ensure interoperability and safe use of the system and relate spatial database with observations and measurements, business, and application layers. The '*application layer*' accommodates ranges of sectors that referenced by a digital twin, mainly to represent physical, social, and legal aspects of a city, including open data services, health, education, utilities, sanitation, urban planning, intelligence building, environment protection, emergency services, and other applications (Percivall et al. 2011 & 2015).

5.6.5 Criterion 5: Fit for purpose technology

The Indonesian SII systems consist of Distributed Network Nodes (DNN) and Network Node Connector (NNC). NNC connects all nodes. DNNs were installed in each of the ministries, national agencies, and local governments. In 2011-2014, ten participating institutes (eight ministries and two local governments) functioned as DNN. In October 2019, there are 230 DNNs from possible 617 institutions in Indonesia, but only 170 connected to the NNC. A web application called "*Simojang*" (https://simojang.big.go.id/) is operational to monitor the growth of the SII development in Indonesia. NNC hosts multiple metadata databases for DNNs and can be searched as a single metadata database. Users can search metadata, access map services, and download spatial data directed from the geoportal.

The technical foundation of the Indonesian SII systems was built based on OGC standards. Its geoportal is capable of managing Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), Styled Layer Descriptor (SLD), and Catalogue Service for the Web (CSW) (Sukmayadi & Indrajit 2012). Indonesian geoportal facilitates users to access both 2D and 3D spatial information through web services (http://dem.big.go.id) and file sharing (http://tides.big.go.id/demnas). The Open SII architecture was presented in Forum Group Discussion held in Geospatial Information Agency in 2017. Jakarta and Bandung were agreed to consider the integration of their SII and smart city system. By using open standards, the SII will have interoperability for smart city systems in facilitating spatial information streams from DNNs, sensor networks, and IoT. Both Jakarta and Bandung use the Comprehensive Knowledge Archive Network (CKAN) (https://ckan.org/), a web-based open source management software, for developing their open data portal. Like OGC's geoportal, CKAN creates, maintains, and presents metadata to allow users to search and discover openly published spatial information services. These cities establish SDI and smart cities in different initiatives that were causing these systems having in a separate policy, platform, and management. Jakarta utilizes ESRI software for distributing 3D city models while Bandung still develops its system using open-source software (Bandung City 2019).

In 2012, together with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, GI Agency, and *Bappenas* developed the Spatial Information Reference Framework (SIRF) using Linked Data Technology (Atkinson et al. 2013). Linked Data uses the semantic web to integrate spatial and statistical information vital for developing urban intelligence (Batty 2012). SIRF connects gazetteers with linked data web to support *Bappenas* in managing a coordinated response in social protection activities (Box et al. 2012). GI Agency is hosting and connecting the SIRF application with the Indonesian geoportal to allow more users (ministries) for various purposes. However, during the interview held in September 2019, GI Agency has not decided to broaden the SIRF services to local governments or smart cities. Representatives from the Government of Jakarta and Bandung have agreed that standardization is necessary for better capturing urban phenomena, infrastructure conditions and allowing third parties to provide interactive tools for the citizens in contributing information to the city. Until now, these cities are relying on real-time services and alert systems provided by government institutions. Meteorological, Climatological, and Geophysical Agency (BMKG) broadcasts weather, climate monitoring, and other earth observations from its sensors across Indonesia, which are required by cities. GI Agency provides live streams for geodetic information from Continuous GPS and Tide Gauge stations for positioning and mapping services as open data. These agencies are responsible for maintaining tsunami early warning systems consisting of four types of sensors in tsunami-prone areas (Lauterjung et al. 2010).

5.7 Conclusion and Recommendation

This chapter presents a real-world implementation of transforming contemporary the SII into the Open SII to be integrated with smart city initiatives in Jakarta and Bandung. Both the smart city and the SII concepts are understood as covering more than technological aspects. It considers policies, organizations, standards, financial and human resources. In a spatial intelligence context, integration of the Open SII and smart city is natural. They share similar components, stakeholders, and purposes (see Figure 5-3 in Section 5.5). Some adjustments need to be made for transforming the SII into the Open SII. The technological aspect also needs to be examined for supporting the smart city initiative. Technological and non-technological aspects should meet the requirement to enable open data and open participation principles, maintain digital twin as open data, achieve interoperability and comparability, fit for purpose technology, support leadership, and sustainable financial and human resources.

The proposed model is the first attempt to develop the Open SII aligned with the smart and sustainable city initiative. We found that legal frameworks and policy aspects are vital to guide all stakeholders to allow open access and open participation that the Open SII and smart city needs. One Map Policy in Indonesia could be helpful if it covers large-scale maps, 3D city models, and VGI and sensor networks to construct digital twins. The Open SII could facilitate such an endeavor. However, the Open SII developers in Indonesian cities should utilize the One Data Indonesia policy as a base for establishing open spatial data governance, making open data and open participation into reality. Indonesia has a complete set of policies in establishing Open SII. However, there is still some space to make it more robust, particularly in creating incentives for stakeholders to publish open spatial data and allow open participation. The GOI should also assess the SII components regularly. Open SII's strength is smart peoples and communities and usability of spatial information, while its successes depend on making them spatially enabled.

The existence of a digital twin published as open data will be the game-changer for Indonesian smart cities. It is a massive challenge for GOI to provide a digital twin for all Indonesian cities. Therefore, GI Agency should expand the One Map policy to cover 3D city models with sufficient LOD and include the much-needed utility maps. The most crucial step is to ensure the local government complies with the national data governance prescribed in the One Data Indonesia policy. Local governments, universities, and professional associations should share knowledge and resources to develop and maintain digital twins. The Open SII should be integrated with the smart city to facilitate open spatial data and open participation. Further developments and researches on the Open SII are necessary to provide lessons learned in improving its design. The integration of the Open SII and the smart city will help cities achieve sustainable developments. While each country and city has specific regulations or policies for data governance, the Open SII approach can be applied in all countries or cities. Therefore, this chapter proposes the implementation of the Open SII beyond Indonesian cities.

6

Implementation of the New SP Information Package of the LADM in Indonesian Cities[4]

This chapter assesses how the proposed SP Information Package may improve information interoperability of land-use plans and visualize RRRs from land-use planning in 3D representation. The first two sections of this chapter present a background of standardization of land information within the land management paradigm to improve ease of doing business. This chapter assesses how the proposed SP Information Package may improve information interoperability of land-use plans and visualize RRRs from land-use planning in 3D representation. The first two sections of this chapter present a background of standardization of land information within the land management paradigm to improve ease of doing business. Section 6.3 discusses the SP Information Package of the LADM. The fourth section describes the redevelopment of the LADM Country profile in Indonesia. Section 6.5 illustrates the strategy to provide land information on Spatial Information Infrastructures (SII) for supporting economic actors in doing business. The development of a proof-of-concept using actual land-use plan data is presented and discussed in Sections 6.6. This chapter is concluded with Section 6.7 and 6.8 that contains discussion, conclusions, and recommendations.

6.1 Introduction

Cities are the economic growth engine that stimulates urbanization worldwide (Bloom et al. 2008 & Colenbrander 2016). In 2007, the total urban population surpassed the countryside (UN-DESA 2019), increasing pressures on urban areas. Dobbs & Remes (2013) projected that in 2025, the 600 largest cities in the world would be responsible for 60% of the total GDP. The European Commission (EC) has identified that 271 metro regions in the European Union (EU) already contributed as much as 62% of jobs and 68% of the Gross Domestic Product (GDP) (Dijkstra & Maseland 2016), making cities vulnerable to urbanization. In responding to this situation, authorities often apply land management techniques to control the supply and use of land and space for economic reasons and balance social and environmental interests. The role of land management in

[4] This chapter is based on the published paper in the Land-use Policy Journal (Indrajit et al. 2021).

supporting the economy of a city is well-recognized in many countries (Dowall et al. 1996, Fekade 2000, and Shatkin 2016). For a coherent understanding, the UNECE (2005) formalized the definition of land management as "*the process of putting the physical resources of the land to good effect.*" As successful land management becoming a prerequisite for economic interests, the World Bank promoted it as an essential factor for business activities. Since 2014, the World Bank (2014b) launched the *Ease Of Doing Business* (EODB) annual reports and started examining land management practices in 190 countries. EODB includes *Dealing With Construction Permits* and *Registering Property* as EODB ranking indicators. The World Bank (2014b) conducts annual surveys for the maturity of the Land Administration System (LAS). It assesses how a country (and cities) securing land and property rights and facilitating investment planning and business growth (World Bank 2014). Inclusiveness of access to land information is also being valued in the EODB assessment for its ability to service economic actors or landowners in making decisions about their land and properties. Land management is evolving and involving more stakeholders. For these reasons, the International Federation of Surveyors (FIG) is recommending countries to modernize their LAS to better managing land information to support sustainable development initiatives (Enemark 2005), including starting and growing business activities (Steudler 2014).

LAS should make a city smarter and spatially enabled (Roche & Rajabifard 2012). LAS should have the capability of facilitating non-government entities through the provision of data and access to relevant land information. Human activities, including doing business, happen in 3D space. It is beneficial for a city to provide a more realistic representation, such as multidimensional visualization, for rights, restrictions, and responsibilities (RRRs) of land (and space). This study uses the Spatial Plan Information Package (SP Information Package) of the ISO 19152 on Land Administration Domain Model (LADM) to improve an LADM country profile closer to the actual situation and develop a 3D representation of RRRs from the urban plan. A Design Research (DR) strategy was used to review the implementation of the SP Information Package for developing 3D RRRs in the two biggest Indonesian cities: Jakarta and Bandung.

6.2 The land management paradigm

The "*Land Management Paradigm*" was proposed by Enemark (2005) to support sustainable development. This paradigm identifies four functions of land management: land tenure (and cadastre), land value, land use, and land development (Figure 1-1 in Section 1). Land tenure manages data about rights (public and private laws) on land or properties. Land valuation focuses on fiscal information on land and properties (land price, transaction price, and mass valuation). Land-use and land development planning create zoning regulations that prescribe characteristics (privileges, prohibition, and obligations) on a specific area of land or space. The land management paradigm acknowledges that information gathered from land tenure (registration) and land valuation processes are essential to support an efficient land market. Simultaneously, the land-use plan and land development are utilized to establish effective land-use management.

In 2014, the International Federation of Surveyors (FIG) re-iterated the importance of "*Cadastre 2014 Vision*" and kick-start the modernization of the Land Administration System (LAS) around the world (Steudler 2014). The"*Cadastre 2014 and Beyond*" vision encourages countries to strengthen their efforts in providing a complete overview of land (and space) and its legal aspects (Steudler 2014). This vision recommends Spatial Information Infrastructure (SII) to facilitate data sharing between stakeholders, particularly landowners, property owners, and economic actors. Taken all together, a modern LAS should be capable of managing relevant information of all the four functions of land management. This capability is the key to achieve sustainable development, especially establishing an efficient land market and effective land-use management for supporting doing business. For making this paradigm into reality, standardization of information from four land management functions is needed to ensure interoperability and allow the integration of land information.

6.3 Spatial Plan Information Package (SP Information Package)

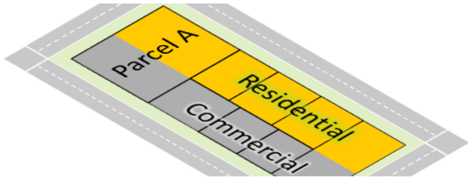
Urban planners often use land-use planning as a tool for integrating a range of policies (Van Straalen 2012). UN-Habitat (2017) recommends that countries and cities need to integrate land-use planning processes to make a city smarter and sustainable. They reconcile the competing interests in determining the urban form and functionality, servicing the public good, and representing the collective values in land-use planning. Land-use planning defines how land and space are used optimally and sustainably for achieving national and local objectives. The land-use plan (or zoning plan) populates and accommodates social, economic, and environmental aspects that influence physical land development. The land-use plan can influence the landowner's property rights by imposing restrictions and responsibilities (Van der Molen 2015). Jacob (1993) noted that land-use planning is often used to manage land supply for various interests. Thus, local governments should construct information interoperability of RRRs, specifically from four functions of land management. They should share land information with relevant stakeholders in standardized and easy-to-understand formats to reuse information. This chapter presents the construction of a spatial representation of RRRs from land-use planning. This study attempts to improve information interoperability for better understanding and decision-making. The level of information interoperability of the land-use plan directly influences the effectiveness of land-use management. It can be expected to positively impact cities' efforts to achieve sustainable development (see dashed lines in Figure 1-1 in Section 1.2).

The International Organization for Standardization (ISO) published the ISO 19152:2012 - Land Administration Domain Model (LADM) standards to provide a foundation for modeling the relationship between people and land (and space), the geometrical (geospatial) components. It also includes documenting information about RRRs. Lemmen et al. (2015) reported that the LADM can make information managed in LAS interoperable while still allowing countries to accommodate local situations (i.e., local requirements, priorities, culture, religion, and behavior) in developing their LAS. Most countries establish their LAS for land tenure or land registration only. FIG endorses the land management paradigm and the modernization of LAS to accommodate all four land management paradigm functions of land tenure (and cadastre), land value, land-use, and land development (Enemark 2005 and Steudler 2014). However, at the moment, only a few countries include land-use plans and documentation of land development.

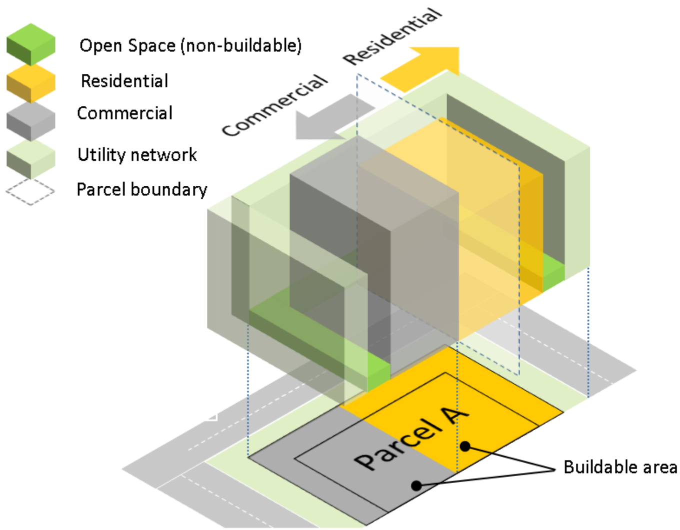
The term "*zoning plan*" is often used as the end product of land-use planning. A zoning plan contains a set of RRRs information for each land unit (allotment) for various applications (i.e., permit, valuation, tax, disaster management) (see Figure 6-1.a). Authorities organize land-use planning in specific time intervals or sporadically based on political dynamics, acceleration of economic investments, or disaster. These dynamics amplify land information complexity in urban areas where land and spaces are more scarce and stacked vertically. In this setting, the land parcel may contain two or more types of RRRs. This chapter classifies space into a buildable area, open space, and utility network classes (see Figure 6-1.b). Each object has different RRRs (i.e., open space as part of a land parcel restricted to build any or permanent construction).

This standard aims to guide countries in developing LASs through conventional conceptual models (Lemmen et al. 2015). The current LADM standard provides sets of guidelines to ensure the information interoperability concerning LA and model the relationship between people and land (or space). The LADM introduced a formal language of RRRs information from land management activities (Van Oosterom & Lemmen 2015). ISO (2012) describes rights as "*activity or class of actions that system participant may perform on or using an associated resource*" with the added note "*a right may provide a formal or informal entitlement to own or do something*." Restrictions are defined as "*formal or informal obligation to refrain from doing something*" and responsibility as a "*formal or informal obligation to do something*."

At the time of writing, the SP Information Package is included as the fifth part of the LADM standard revision proposal. This package contains three main classes: *SP_PlanBlock*, *SP_PlanGroup*, and *SP_PlanUnit* (see Figure 4-9 in Section 4.3). *SP_PlanUnit* class depicts the smallest unit from a zoning plan or a detailed plan and contains a spatial representation (i.e., zoning plan). *SP_PlanBlock* accommodates land-use functions. Both classes may contain geometry and legal expressions (constructed, agreed, and approved) from spatial planning processes. The *SP_PlanGroup* class allows hierarchy in spatial planning (e.g., national spatial plan, state/province spatial plan, and city spatial plan). In a specific condition, *SP_PlanBlock* can be used to model land-use plans at national and provincial levels. The *SP_PlanBlock* and *SP_PlanUnit* classes include administrative and spatial sources and supplementary documents (Indrajit et al. 2020a). Administrative and spatial documents are facilitated by *LA_AdministrativeSource* and *LA_SpatialSource* classes, respectively (Lemmen 2012).



a. Typical zoning regulation on land parcel boundary



b. Implication of urban plan on a land parcel "A"

Figure 6-1. The element of spatial units in a complex urban setting

The administrative package in the LADM provides the abstraction of the three subclasses of LA_RRR: *LA_Right*, *LA_Restriction*, and *LA_Responsibility*, and the class Basic Administrative Unit (*LA_BAUnit*) (Figure 4-10 in Section 4.3). The *LA_BAUnit* is associated with zero or more parcels (represented in the class *LA_SpatialUnit*) with homogeneous RRRs (ISO 2012). For cities, authorities design land-use plans to prescribe restrictions and responsibilities on particular zones. A land-use plan accommodates criteria in public laws and public aspirations (Indrajit et al. 2020a) (i.e., maximum height restriction for building construction or responsibility to sort waste before disposal). The current version of the LADM provides *LA_BoundaryFace* class to construct a 3D representation and *VersionedObject* for accommodating the temporal aspect of RRRs. These two classes are instrumental in constructing 4D (3D and temporal) RRRs crucial in granting location and business permits in Indonesian cities. The revision of the LADM offers two new packages (spatial plan information and land valuation *enable two-way information flows and 3D web visualization capability*), which helps authorities ensure consistency and integrity of land information (Lemmen et al. 2019).

6.4 Updating the LADM Country Profile using SP Package

In Indonesia, the legal framework and policies at the national level mandate government institutions to provide access to land information supporting better collaboration in land management activities. However, land management in Indonesia is facing challenges. Many stakeholders still maintain data silos and develop their own '*standards'* for the data they produce. This situation leads to the information asymmetry phenomena, resulting in the failing integration of RRR information in land-use (urban) plans. This study applied the Design Science Research (DSR) method proposed by Hevner, A., & Chatterjee, S. (2010) based on its capability of improving the ongoing system. The SP Information Package was applied to improve Indonesia's LADM country profile, which provides a better description of the actual (legal) situation. This package is also used for constructing a 3D land-use plan for Jakarta and Bandung. This study considers the proposed SP Information Package and the 3D prototype are considered artifacts to be analyzed in the Indonesian context. These artifacts provide a foundation for improving the Indonesia LADM country profile and constructing data models for the land-use plan. The following section shows prototype developments and institutional arrangements for sharing and reusing 3D land-use plans. The problems and artifacts are then continually being evaluated. The DSR will assess innovations made from the artifact design and organization intervention: the revised Indonesian LADM country profile, 3D representation of land-use plan, and institutional rearrangement to allow two-ways land information sharing. Enemark et al. (2018) highlight positive steps made by Indonesian cities in constructing a supporting environment for the land management paradigm. Indonesian constitution acknowledges land and space (above and below the Earth's surface) as public goods.

The State may still recognize private ownership of land and properties by imposing restrictions and responsibilities on land and space in various laws and regulations. The Disaster Management Act and the Spatial Planning Act protect and regulate the use of land or space for public interests. These laws and the Local Government Act (2014) mandate local governments to establish information systems to support land management and facilitate access for communities to land information. Indonesia develops its land management policy based on the Basic Agrarian Act and the Spatial Planning Act. Under these laws, *Badan Pertanahan Nasional* (BPN), a national land agency, is mandated to secure legal certainty (*rechtskadaster*) of land and space through three activities: cadastral mapping, legal documentation, and land registration. At the time of writing, BPN operates the Computerized Land Office web-based system (*Komputerisasi Kantor Pertanahan/KKP-web*), an online application based on the LADM (Pinuji 2016). On the other hand, the local government may update land-use plans in five years or respond to various types of disasters. Therefore, a zoning plan must have spatial representation in the Indonesian LADM country profile.

The Government of Indonesia (GOI) launched the Indonesian Spatial Data Infrastructure (or Indonesian Spatial Information Infrastructure/SII) to facilitate ministries and local governments in sharing spatial information (Indrajit 2018). Guided by a spatial plan and the permitting mechanism, authorities use various land information to grant parties privileges or impose restrictions and responsibilities in utilizing or benefiting from land or space. In modeling RRRs, this study anticipates a land parcel with two or more zoning plans (see land parcel boundary in Figure 6-1.a) by reusing the class LA_BoundaryFace classes to construct a spatial representation RRRs and anticipate a land parcel's subdivision. The class *SP_PlanGroup* is used to accommodate land-use policies in the upper levels, such as the National (*Rencana Tata Ruang Wilayah*/*RTRW Nasional) and the Island-based (RTRW Pulau*), and the Provincial (*RTRW Provinsi*) Spatial Planning. The *SP_PlanUnit* class shall contain the detailed zoning regulation (*RDTR*) on each allotment or space regulated in the Spatial Planning Act. Collaboration between all levels of government in spatial planning in Indonesia is inevitable. The Spatial Planning Act prescribes a hierarchical structure following the administrative jurisdiction, sharing land information as the reference to lower levels (see Figure 3-2 in Section 3.4). The lower spatial planning level must refer to (and comply with) the upper-level spatial plan.

The Indonesian detailed land-use plans (*Rencana Detil Tata Ruang /RDTR*), the most detailed land-use plan, include a list of construction projects at the lowest spatial (but most detailed) planning level for public services or private projects. Land development plans use RDTR as the basis for issuing construction permits. In the recently enacted Job Creation Act (2020), RDTR is the primary source of information for the land development plan and granting permits, including highly debated environment permits. In practice, BPN provides and manages information concerning rights and governing land supply to cities and rural areas (see Yellow boxes in Figure 6-2). Simultaneously, the Spatial Planning Act mandates that local governments control land and space utilization (Green boxes in Figure 6-2). Black lines represent "*elements*," and dashed black lines represent "*referencing*." Local governments maintain the grey boxes while BPN is mandated to organize blue boxes. The white boxes in Figure 6-2 indicate shared responsibilities between local governments and BPN. The land-use plan aggregates sectoral policies to create restrictions and responsibilities of each allotment or space while land tenure prescribes rights over land parcels. The integration of information about land ownership (private laws) and public laws in investment is mentioned in the Capital Investment Act.

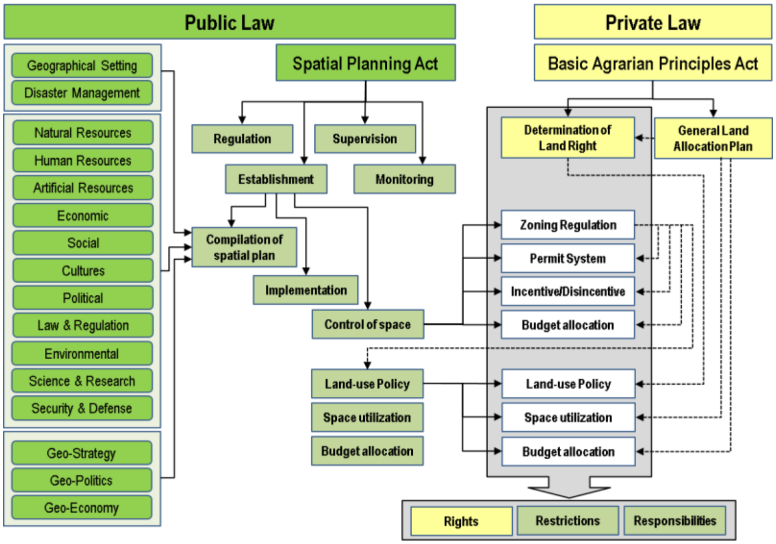


Figure 6-2. Spatial Planning and RRRs.

The Local Government Act promotes spatial plans as a "*must-have*" data for public services and mandates local governments to develop and maintain information systems. Government Regulation on Spatial Planning instructs the authorities to disseminate land-use plans to government institutions and society. However, there are gaps in integrating private and public laws concerning land management at national and local levels (*Bappenas*, 2012). Data silo practices and a lack of interoperability, data completeness, and data quality as major drawbacks in spatial planning processes (*Bappenas* 2016a). This chapter considers three aspects of constructing a country profile: 1. Identification of spatial units from land-use planning; 2. Identification of parties on land tenure and land-use planning; and 3. Identification of RRR information from zoning regulation of each allotment or space from land tenure and land-use planning. In Indonesia, land-use plans are containing zoning plans and criteria for non-buildable areas within the land parcel. Most cadastral activities in Indonesia are using 2D, with 3D only applied for apartments and tall buildings as strata titles. The Indonesian LADM country profile uses the Spatial Plan Information Package from Indrajit et al. (2020a). The updated country profile still accommodating information and documents collected by land registration in the previous version while adding a land-use plan to accommodate multiple sectoral policies (i.e., social, environment, economy). Figure 6-3 shows the result of the LADM country profile for Indonesia using the SP Information Package. The core LADM classes (light blue boxes) are by law mandated to BPN. Local governments will supervise spatial plan information classes (light green boxes). The white boxes are the shared classes and will be managed collaboratively between BPN and local governments, while pink boxes contain typical RRRs according to the Indonesian legal framework. (see Figure 6-3).

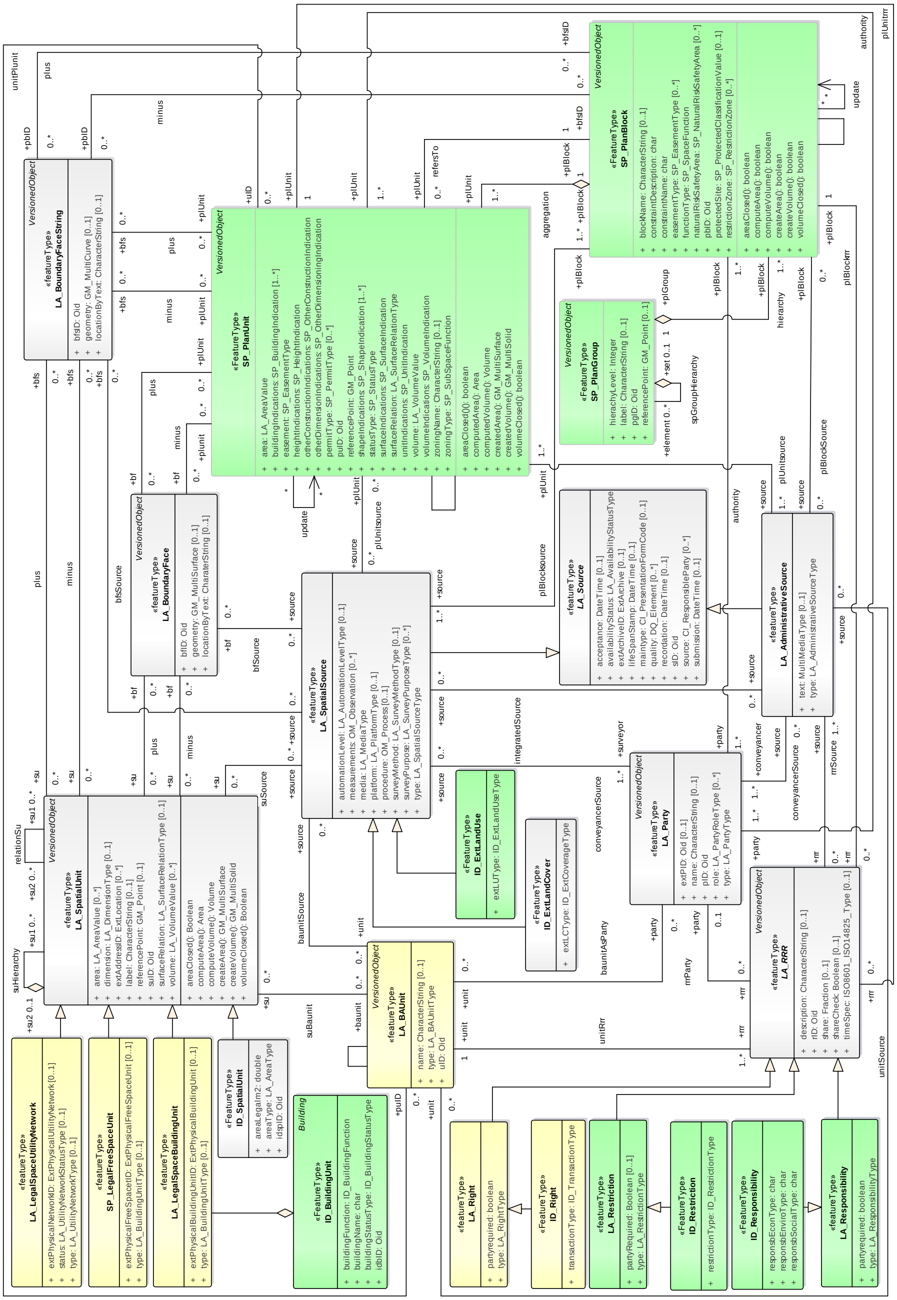


Figure 6-3. Improved Indonesia LADM Country Profile using the SP Package.

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This study implements the extended abstraction of RRRs proposed by Paasch et al. (2015). The RRRs information from private and public laws is assigned in separate classes: *LA_Rights*, *LA_Restrictions*, and *LA_Responsibilities* classes. Supplementary data were assigned with *LA_Source* and subclasses classes (i.e., regulations, surveying data, or other legally binding documents). A literature study was conducted and found at least eighteen rights on land parcels, eight restrictions, and five responsibilities related to land tenure and land-use planning (see Tables D-1 to D-3 in Annex D). These classes are attached with a 3D representation of RRRs via *LA_BoundaryFace*. This class describes a 3D volumetric land parcel (space) by boundary surfaces. In contrast, *LA_BoundaryFaceString* class represented more traditional 2D parcels, but with the interpretation as a column of volumetric space (see land parcel boundary in Figure 6-1.b). In Indonesia, land tenure activities register types of rights on each land parcel. At the same time, zoning plans represent multiple sectoral policies (i.e., social, environmental, economy) (see Figure 6-3).

6.5 Integrating land administration into Spatial Information Infrastructure

The availability and accessibility of a land-use plan are vital for the local government to ensure effective land-use management. At the same time, prospective investors and landowners use land-use plans for making decisions for economic purposes. Indonesia's land-use plans contain information about restrictions and responsibilities (i.e., limitation on activities or specifications and obligations to perform activities) or rights (privileges or benefits), essential for landowners or prospective investors. In the digital era, this information should be machine-readable and machine-actionable for users to access and reuse. Therefore, as authoritative data custodians in land management, local governments must ensure information interoperability and accessibility of land information for all stakeholders. More than three-decade ago, FIG has identified that the traditional LAS might be exposed to information asymmetry when incomplete and unreliable land information is used by a broad range of legal land applications (Kaufmann & Steudler 1998). Information asymmetry happens when some actors hold more knowledge of a particular commodity or product than others at a specific timeframe.

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Spence (1973) illustrates the "*signaling*" concept where a credible party conveys information about the product to other parties. In this case, authorities disseminate public information (i.e., land-use plan) as "signals" to all business activities. Simultaneously, economic actors perform "*screening*" to access information from many sources, mainly from the authorities. Screening includes accessing, filtering, and reusing the accurate information of specific commodities (i.e., land or space) being released into the market. Information asymmetry is considered a sign of an unhealthy land market (Feder & Feeny 1991). The higher risk of information asymmetry might happen if land management delegated its functions, roles, and tasks to separate authorities (Bennett et al. 2006). In this institutional arrangement, the lack of interoperability and building silos of information may cause LAS to be vulnerable to information asymmetry that impedes stakeholders from integrating land information and creates an uneven opportunity among economic actors. In the longer term, unequal access to land information may widen income disparity in society (Jetzek et al. 2013) and hinders the city's effort to achieve sustainable development. Taken all together, information asymmetry in land-use planning adds legal and financial uncertainty on land and property against unpublished zoning regulations for landowners and prospective investors. Geospatial communities have long acknowledging information and technological interoperability as the critical element of a spatially enabled society (Steudler & Rajabifard, 2012). A modern LAS manages all relevant land information for all land management functions with all information to be interoperable, including land-use plans. Information interoperability allows further information integration while ensuring a consistent understanding. Thus, economic actors can perform "*screening*" (discovery, search and use) of land information before making decisions (i.e., selecting the location and acquiring the land or property), obtaining the construction permits for their facilities, and registering their (immovable) properties. Information interoperability is a prerequisite for any information shared via data infrastructure, particularly in Spatial Information Infrastructure (SII). Van Oosterom et al. (2009) introduce four maturity levels for LAS with standardization as the basic criteria (first level) to ensure interoperability for the whole system. The second level is the existence of connectivity to exchange land information between stakeholders. The capability of LAS to facilitate information integration is a sign of the third level of maturity. The highest level is reached if LAS can outreach broader communities to reuse land information.

The 1998 reformation movement called accountability on governance and transparency and. Ten years later, the parliament enacted the Public Information Disclosure Act (2008) to safeguard transparency and access to public information. This Act includes any spatial information funded by the government budget as public information, including spatial information, to be accessible to the public. Presidential Decree on the National SII was decreed in 2014 to provide the legal foundation for spatial data sharing. This regulation acknowledges a two-way information flow in exchanging spatial data within the Indonesian SII system and citizens as data producers. In Indonesia, authorities manage public (land) information in four functions of land management (land tenure, land valuation, land-use planning, and land development planning). This information is helpful for governments and landowners, and other economic actors in broad ranges of decision-making, from selecting sites for investments, monitoring business performance, and evaluating real-time situations for planning for growth. The "*THIS*" approach mentioned in the previous chapter requires a modern LAS integrated with the SII for allowing all stakeholders (i.e., BPN, local governments, landowners, and economic actors) to access and exchange land information for managing land (and space). Thus, failure to ensure information and technological interoperability may create asymmetric information among land management stakeholders in Indonesian cities. To support data-driven decision-making, GOI initiated a series of discussions since 2006 on strengthening national data management as part of Open Government Indonesia (*Bappenas* 2012). In 2019, GOI decreed the "*One Data Indonesia*" (ODI) regulation to ensure the availability, quality, integrity, accessibility of data for planning, implementation, evaluation, and development control. Data producers within government institutions do submit and store data to data custodians in each institution. Transparency and reliable information infrastructures are needed to facilitate data sharing and reduce the information asymmetry among stakeholders (Indrajit et al. 2019). The GOI launched the "*One Map Policy*" (OM) Policy as part of the 8th of Economic Stimulus Package Policy in 2016 to ensure the quality of spatial information managed by government institutions. This policy aims to provide quality thematic maps at 1:50,000 to handle boundary dispute-triggered conflicts and overlaps in land utilization permits and enforce land-use plans implementation.

6.6 Case Study: Indonesian Cities

The New Urban Agenda (NUA) echoed the land management paradigm by encouraging countries to establish a robust land information inventory system (UN-Habitat 2017). This agenda promotes transparency in national and sub-national governments for effective policy and land management towards sustainable development. The NUA promotes the development and enhancement of a participatory data platform for sharing spatial information and knowledge among stakeholders. However, in reality, many government institutions are still practicing "*silo thinking*" instead of delivering land information to governmental institutions and broader society (Ferraro 2008, Thellufsen et al. 2009, and Pettit et al. 2019). In her fundamental work, Arnstein (1969) prescribed transparency as the foundation of participative activities. The Open Definition 2.1 characterizes "*open*" as allowing "*anyone can freely access, use, modify, and share for any purpose*" through open works and open licenses (Open Knowledge Foundation 2017). OECD (2017) highlighted the G20's Open Data Principles: 1) open by default; 2) timely and comprehensive; 3) accessible and usable; 4) comparable and interoperable; 5) for improved governance and citizen engagement; and 6) inclusive development and innovations. Scientific communities introduced Findable, Accessible, Interoperable, and Reusable (FAIR) Guiding Principles as a "*technical specification*" to improve discovery, access, integration, and reuse of scientific materials for wider stakeholders (Wilkinson et al., 2016). FAIR Guiding Principles aim to implement '*good data management*' practices to improve information interoperability for knowledge integration and reuse of information by relevant stakeholders. FAIR Guiding Principles recommends standardization to make open data interoperable, machine-readable, and machine-actionable.

In 2018, the GOI launched Online Single Submission (OSS), an online application for the single nation gateway for issuing permits (Deloitte 2018). The ODI regulation provides a legal foundation for nationwide data governance and governs data producers and data custodians to support the OSS systems (Figure 6-4). The OSS attempts to simplify the process to obtain business permits, such as construction permits and business licenses. BPN and local governments are the responsible parties in compiling the RRRs information within the OSS system. BPN can share its land registration database (KKP-web) while the local government shares the land-use plan to the OSS system. However, in reality, standardization of RRRs information in Indonesia is still in the early stages, forcing authorities to do manual work to examine and interpret various documents prone to human errors, moral hazards, and causing information asymmetry. This situation challenges integrating the RRRs information from land registration and spatial plan to support the OSS as planned. Information asymmetry may be imposed when authorities and economic actors had different access to land information or lack of information interoperability. Therefore, this study implemented the proposed SP Information Package to ensure interoperability of land-use plans to pave ways to make it understandable, meaningful, machine-readable, and machine-actionable.

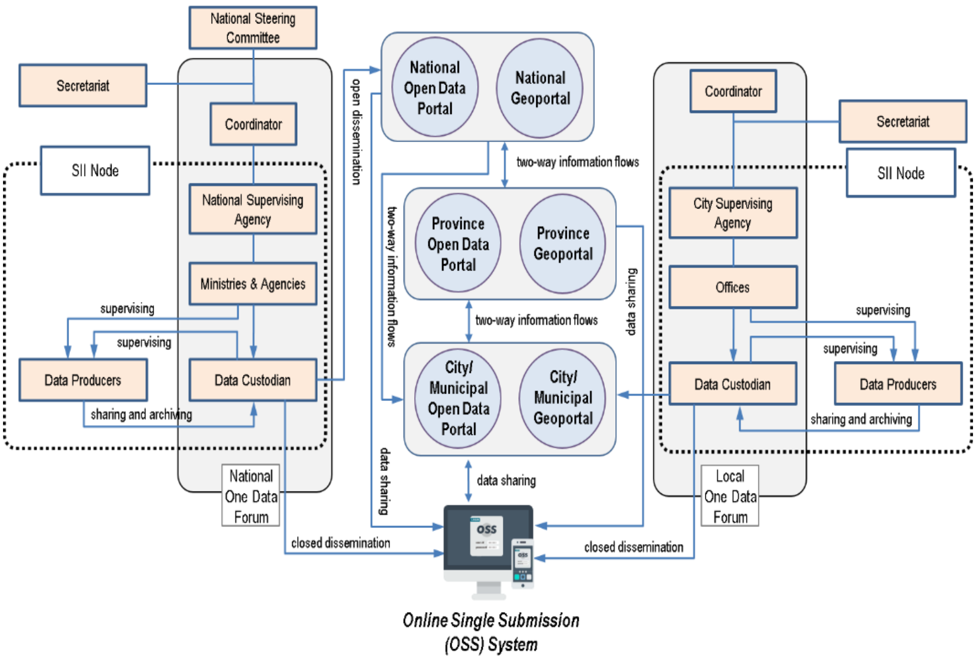
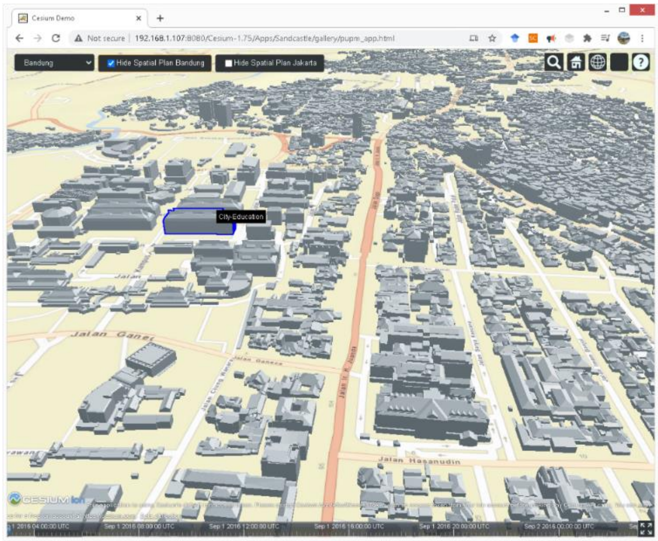


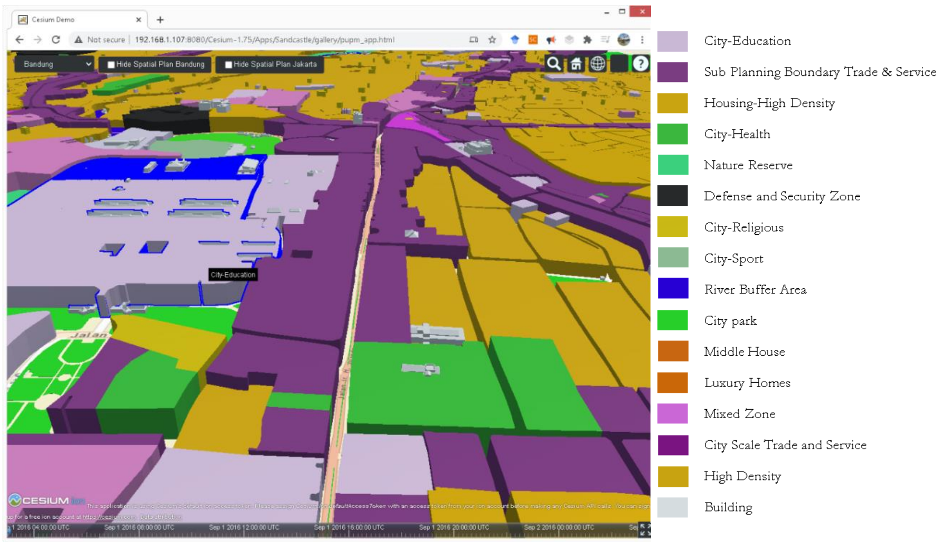
Figure 6-4. The SII and the Online Single Submission (OSS) system under the '*One Data*' Indonesia Regulation with the national level (left) and the provincial/city level (right).

A modern LAS can be part of the spatial data-sharing ecosystem to allow more stakeholders to share land information. The United Nations-Global Geospatial

Information Management (UN-GGIM) (2015) includes land information into Fundamental Geospatial Data Themes (FGDT) for SDGs (Hadley & Carius 2019) and recommends these layers through the National SII (Scott & Rajabifard 2017). Cadastre and land-use were included as FGDT. For this reason, countries are urged to establish their SIIs to enable participation from all stakeholders by exchanging land information. An increase in the land transaction or transfer of land and property rights demands some degree of "*openness*" of LAS and SIIs to facilitate landowners and economic actors. As the value of maps depends on their usage and the societal benefit (Van Loenen & Van Rij 2008), so does land information (Elwood 2008). The open data principles can make society spatially enabled and create more values from reusing spatial information (Van der Molen 2007 and Williamson et al. 2010). Therefore, it is natural for LAS to be connected and built on the same platform as the SII systems (Van Oosterom et al. 2009 and Roche & Rajabifard 2012) to facilitate sharing and reusing spatial information (Van Loenen 2006). In this setting, the SII needs to harness new data sources from authorities, landowners, and economic actors, including non-traditional and low-skilled spatial data producers. Jakarta and Bandung City have provided zoning regulations and detailed land-use plans at a map scale of 1:5,000. The zoning plans (represented in the class *SP_PlanBlock*, containing the *SP_PlanUnit* class) and building map from these two cities are in 2D shapefile files. Bandung City has 21,429 zones, while Jakarta consists of 37,378 zones. These zoning plans consist of physical and activity criteria categorized as restrictions, including building height limits and free spaces (e.g., roads). This study implements the proposed SP Information Packages for the revised LADM (for the legal objects) and *CityGML* version 2 standards for developing the spatial representation of RRRs. Each zone in these cities is subject to volumetric limitations for landowners and developers in utilizing their land and spaces, including physical height restrictions and specific responsibilities (see Tables D-1 to D-3 in Annex D). Quantum GIS® has been utilized to extract, transform, and load data from/to the PostgreSQL database. UML Class FME software was used to create the 3D spatial representation. Instead of implementing *CityGML* for the abstract objects: *LandUseType* and *LandUse* classes, this study follows the Ministry Regulation on Spatial Plan Database for the planned land-use code list (see Table B-1 to Table B-4 in Annex B). The RRRs information is managed in different classes but related to the spatial representation described in the Indonesian LADM country profile. It is disseminated in the Batched 3D Model (b3dm) format using *CesiumJS* to allow interactive exploration and query by the end-users (see Figure 6-5 & Figure **6-6**). The architecture of the prototype shown in Figure 6-7 is expected to deliver 3D RRRs for users to explore through the Internet. This study develops a prototype to deliver a 3D representation of the RRRs with the system's architecture.

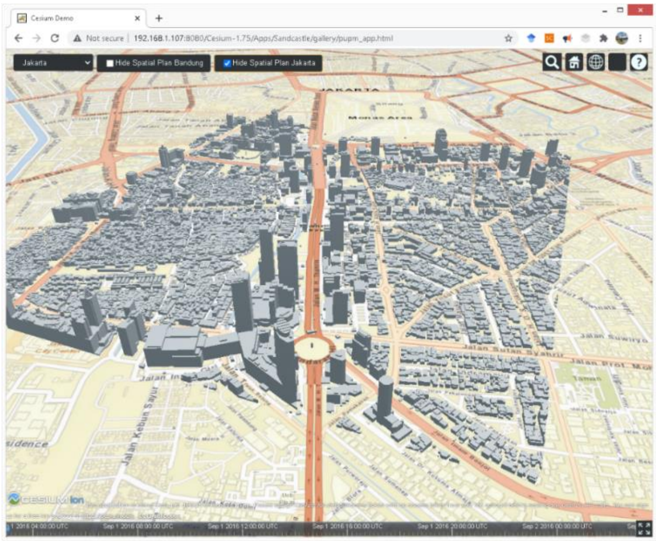


(a) 3D City model of Bandung City (Data provided by the City of Bandung)

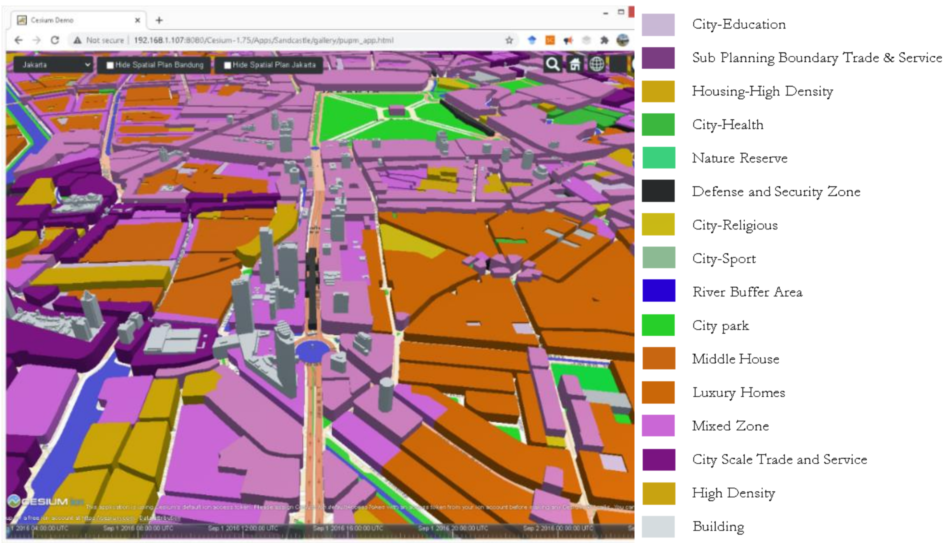


(b). 3D Land-use plan of Bandung City

Figure 6-5. Visualization of 3D representation of RRRs of Bandung, City (Institute Technology of Bandung) using SP Information Package from the updated LADM Country Profile.
Note: some buildings exceeding the height limit governed in the urban plan.



(a) 3D City model of Jakarta City (Sample data provided by the visicomdata.com)



(b). The 3D Land-use plan of Jakarta City

Figure 6-6. Visualization of 3D representation of RRRs of Jakarta, City (near to National Monument) using SP Information Package from the updated LADM Country Profile
Note: some buildings exceeding the height limit governed in the urban plan.

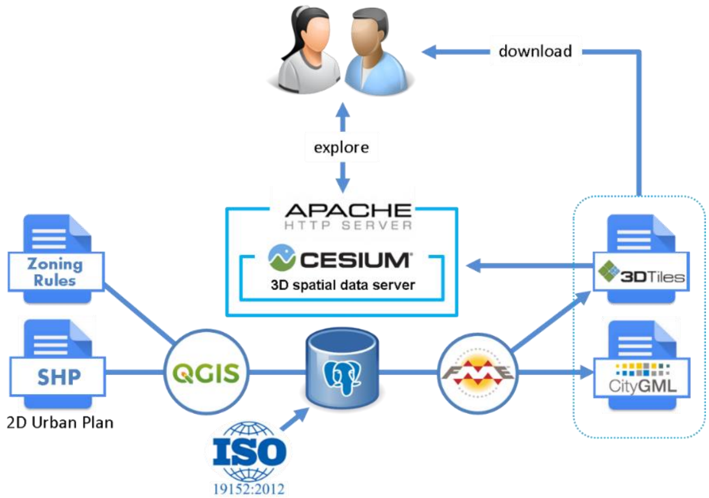


Figure 6-7. The architecture of the prototype of the 3D Land-use plan[5].

6.7 Discussion

Information and technical interoperability allow land information to be machine-readable and machine-actionable, enabling more applications and automation. This section provides an assessment of the proposed SP Information Package for the Second Edition of the LADM standard, employing this new (proposed) package to improve Indonesia's LADM country profile. The two biggest Indonesian cities (Jakarta and Bandung) are presented in this study as showcases with a prototype of 3D visualization throughout the Internet, allowing maximum outreach for interactive exploration and querying. There are three critical areas for implementing the SP Information Package. Subsection 6.7.1 consists of the standardization of RRRs information from spatial planning processes. Subsection 6.7.2 discusses the institutional arrangement for implementing the proposed LADM Edition II within the Indonesian SII context (based on a new strategy of One Data Indonesia policy). Section 6.7.3 discusses the technical aspect of implementing the updated LADM country profile into the national database and the SII systems.

6.7.1 Standardization of RRRs information from the spatial plan

The interoperability of information is crucial in the land management paradigm, mainly to make land information understandable, machine-readable, machine-actionable and reusable for broader applications, systems, and users. As one of the end-products of land management activities, it is inevitable to standardize a spatial plan to ensure RRRs information interoperability. The emergence of the web- and mobile-based applications

[5] The prototype is available via http://pakhuis.tudelft.nl:8080/edu/cesium74/Apps/pupm2/.

built on the shared digital platform needs interoperability enabling automation of public services as an online permit system or a service for land-use (urban) plan monitoring. Countries can study the proposals for revising the LADM standard to improve information interoperability of land-use plans and develop LAS. However, the ongoing LADM revision will extend to the land-use plan with the newly proposed SP Information Package. The SP Information Package will likely support implementing the recently enacted Job Creation Act (UU Cipta Kerja) (2020). This Act indicates that spatial planning should consider a volumetric representation due to height, depth, and distance restrictions. For this reason, this study applies the SP Information Package as proposed for the revised LADM for a better implementation of the Indonesian LADM country profile (see Figure 6-3). In Indonesia, local governments are the leading authority in (detailed) spatial planning. Planners consider land ownership and rights as a foundation and input in designing spatial plans. Our assessment found that the proposed LADM country profile is suitable for improving land management and permit system. The *CityGML* framework represents the actual buildings, as physical reference objects, in city-wide applications such as business permits.

6.7.2 Institutional arrangements for implementing the revised LADM in SII

In today's globalized and digital era, land management requires interoperability and a suitable environment for sharing data among economic actors worldwide. Our study is an extension of work initiated by Van Oosterom et al. (2009) that considers land information as the cornerstone of SII. This chapter presents the implementation of the land management paradigm and modern LASs capable of organizing land management functions (land tenure, land valuation, land-use planning, and land development). This study also provides an approach to implement the LADM in a networked system (web services) approach such as the SII, allowing government institutions and economic actors to exploit integrated land information for decision-making. In the Indonesian context, the '*One Data*' Policy is suitable for supporting a modern LAS. Further, this regulation will strengthen the LAS by enforcing participation and promotion of standardizations and institutional arrangements. On the other hand, the current '*One Map*' Policy needs a realigned scope, allowing map production at a scale and Level of Detail (LOD) suitable for land management. Both Jakarta and Bandung are organizing smart city projects and city-level SII, facilitating a spatially enabled society to access land information that complies with open data principles. In Indonesia, the LADM is well-known by experts and officers in cadastre communities and national land agencies, but not local governments. Therefore, it is essential to extend the usage of the LADM beyond land offices and cadastre communities and start involving local government and planning communities to make the land management paradigm into reality (see Figure 6-2, Figure 6-4, and Figure 6-8).

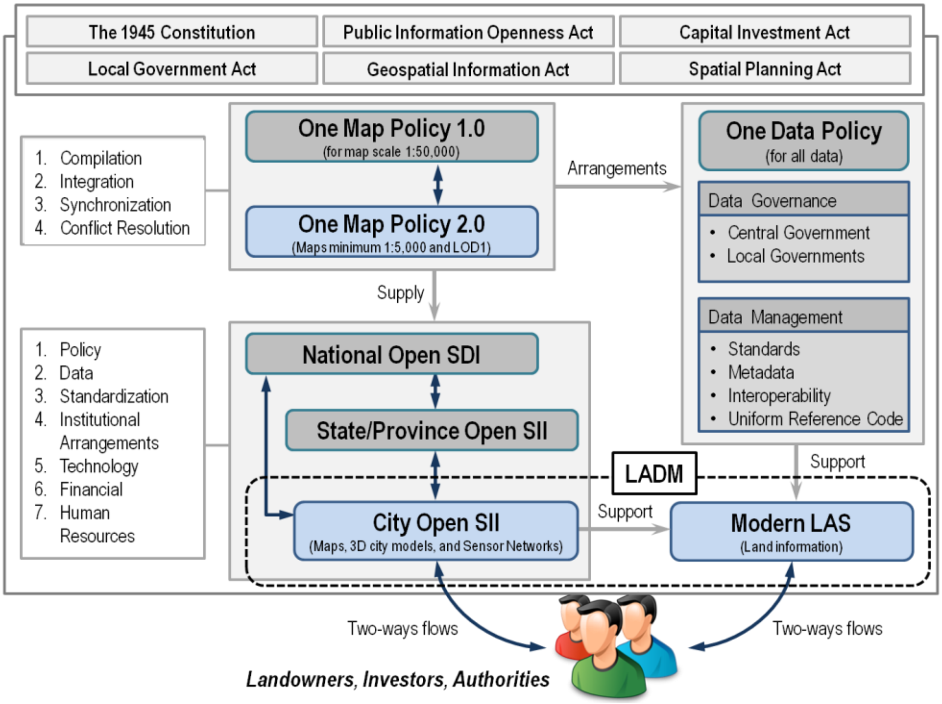


Figure 6-8. Institutional rearrangement based on One Map Policy and One Data Policy .

6.7.3 Technical aspect for managing and disseminating 3D spatial plan through the SII

The Spatial Planning regulation mandates Jakarta and Bandung to compile the zoning plan in 2D from the topographic map and aerial photogrammetric imagery at the scale of 1:5,000. However, a 2D representation is inadequate to support the OSS systems for issuing the construction permits prescribed in the Government Regulation World Bank's EODB guidance. Therefore, this study proposes the zoning plan to be provided at least at a map scale of 1:1,000 and LoD1 (with 3D representation) to support authorities in issuing permits in the OSS and EODB's Dealing With Construction Permit. The proposed SP Information Package in the revised LADM standard is helpful to enforce RRRs information interoperability and spatial representation. *CityGML* or IFC as standard for spatial data exchange is essential to be accommodated in SIIs. This study found that current geospatial technologies can provide two-way land information flows when economic actors can access and share relevant land information in land management. However, not all local citizens in Jakarta and Bandung can afford high-speed internet bandwidth, and internet connection reliability is lower than in developed countries. This study modifies the data package for delivering the 3D urban plan and 3D building into a smaller size to overcome data transfer limitations.

Using unstandardized land-use (urban) plans is technically challenging and time-consuming, particularly for integrating information and analysis. The revised LADM for Indonesia is an approach to standardize the land-use plan of this country's two biggest cities. The country profile developed can be implemented as the core task for modernizing LAS in cities to reduce information asymmetry between stakeholders in land management and improve the doing of business in Indonesian cities. The 3D web GIS prototype developed in our research is a proof-of-concept implementation for the updated LADM country profile and integration into the SII components. Assessment of effectiveness and efficiency in the quasi-real context is required to improve the framework and share 3D RRRs with broader society. An experimental improvement in sharing the two-way 3D RRRs information flow of our implementation is planned to be completed. A higher-level of usability analysis of the improved prototype is being prepared for publication. This study is the first attempt to implement the SP Information Package of the proposed revision of ISO 19152 using two actual land use plans data: Jakarta and Bandung. Consequently, many improvements should be made, mainly integrating 3D cadastre with the 3D land-use (urban) plan for supporting permit systems, disaster management, environmental analysis, and fiscal cadastre (taxation, valuation, and transaction) studies.

6.8 Conclusion and Recommendations

Information and technical interoperability are essential for allowing economic actors to share, integrate, and reuse land information to support participatory spatial planning activities. Indonesia's LADM country profile has been extended and improved using the proposals for a new SP Information Package for inclusion in the LADM Edition II, emphasizing interoperability to RRRs information and 3D spatial information. Cities need to have their land-use (urban) plan and cadastre represented in 3D format. The recent advancement in a 3D spatial database and 3D visualization over the Internet allows cities to maintain their land-use (urban) plan and cadastre data in 3D and disseminate them to broader society. This study shows that the proposed SP Information Package could be implemented in land (or cadastre) agencies and local governments in a networked environment such as the Spatial Information Infrastructure. Information from the spatial (zoning) plan combined with RRR information is essential for any permit system. It contains information that can affect financial and legal impacts for authorities, landowners, and economic actors. Therefore, it is inevitable to have a standardized spatial plan to ensure interoperability with RRRs information.

Implementation of the SP information package will support the better-protected land market in two ways: instructing data custodians to intensify signaling actions and allowing users to perform screening. The performance of participation by (potential) stakeholders depends on transparency. Thus, a city could harness its society to be spatially enabled - where relevant land information is published based on open data principles. All stakeholders can share land information in two-way information flows. The World Bank's EoDB is the perfect example for countries to use international standards to facilitate more stakeholders globally and autonomously. A country may adopt the FAIR Guiding principles to ensure its LAS interoperability to enable users (human and machine) to reuse land information. A contemporary Spatial Information Infrastructure (SII) is in support of the maintenance of authoritative land information. However, in the Indonesian context, the legal framework allows society to contribute land information and contribute maps to the SII initiative. The '*One Data' Indonesia*' (ODI) policy supports the land management paradigm vision and the modernization of LASs through data governance and data management. The SII has long advocated for facilitating relevant stakeholders in sharing and updating land information. Information asymmetry can be reduced with well-implemented interoperability between databases and with sharply increased transparency and accessibility. International standards are essential to guide countries and industries in making land information machine-readable and machine-actionable. Therefore, it is recommended to perform further research in information interoperability and implementation of open data in land management, mainly supporting ease of doing business. This study recommends that local governments provide an accurate Digital Terrain Model for the entire urban area using advanced 3D mapping technologies (i.e., LiDAR surveying techniques). The proposal for revising the LADM contains packages that can provide standardized information about people, land, and relationships. It is critical to fasten the revision process of the LADM to help countries better utilize land information to improve their EODB rank. However, the proposed SP Information Package needs to be investigated for integrating land tenure and land-use planning, making it easier to support land valuation and land development activities (for example, issuing permits). The positive result of the LADM country profile improvement is encouraging. Countries should examine the SP Information Package to improve their LAS. This study also showed that further research is needed to transform the SII to the Open SII to facilitate stakeholders' sharing of relevant land information.

7

The PUPM Prototype for Indonesian Cities based on Digital Triplets[6]

Sustainable Development Goals (SDGs) prescribed justice, strong institutions, and partnerships for the goals at all jurisdictional levels to encourage citizens' participation. Developing an application for participative monitoring of the implementation of urban plans is crucial to detect challenges and evaluate alternative scenarios for achieving SDGs' targets and indicators. This chapter presents the development of a web 3D GIS prototype that enables two-way information flows and 3D web visualization capabilities to support Participatory Urban Plan Monitoring (PUPM). Sections 7.1 and 7.2 presents the context of PUPM. Section 7.3 focuses on digital triplets for monitoring the implementation of the urban plan. The construction of a 3D urban plan in two Indonesian cities is illustrated in Section 7.4. The development of a 3D web application for supporting PUPM is explained in Section 7.5. Section 6 contains a usability analysis. The last section contains conclusions and future research.

7.1 Introduction

Monitoring of the implementation of the urban plan has never been more critical. Murata (2004) demonstrates multidimensional representation for urban planning processes, mainly to compare the actual urban objects and urban plan. LeGates et al. (2009) and Batty & Hudson-Smith (2012) argue that the combination of 3D representation and innovation in Geo-ICT has the potential to assists stakeholders, both authorities and local citizens, in managing their land and space. Cities must collaborate with society in land management. The digital transformation highlights the importance of a spatially enabled society to exploit land information. A combination of multidimensional representation and collaboration is believed to make a city and its society smarter. Michael Batty (2018) proposed 3D city models to represent physical objects of a city and near real-time updating systems (i.e., sensors) as a digital twin of a city. This chapter presents the development of 3D GIS that can perform two-way information flow among stakeholders

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[6] This chapter is based on the peer reviewed and published paper in the FIG 2021 Conference

for supporting Participatory Urban Plan Monitoring (PUPM). Also, this chapter introduces a digital triplets terminology to represent legal objects in the urban area. Digital triplets shall accommodate a complete view of the legal situation and consist of information about Rights, Restrictions, and Responsibilities (RRRs) of an object (land parcel or space) in urban areas from four land management functions (land tenure, land valuation, land-use planning, and land development. Similar to the digital twin, digital triplets use 3D representation and have updating systems to continuously mirror an abstraction of legal situations of objects in urban areas. A participatory approach for urban monitoring has the potential to update and compare digital twin and digital triplets. This approach is taking the benefit of local citizens reporting a change in the urban area. Moreover, it can be applied to examine the conformance of the actual condition with prescribed legal documents from land-use planning. However, this information should be standardized as they correspond with the same reference, a three-dimensional space.

This study considers the current policy and institutional rearrangement of the Spatial Information Infrastructure (SII) in Indonesia, transforming one-way data sharing and 2D to a collaborative approach and 3D capabilities. Furthermore, this study provides a participatory urban plan monitoring prototype to exchange 3D information on the Open SII platform. The output indicates that our framework can support participatory urban plan monitoring in cities. This chapter is concluded with a focus on the effectiveness and efficiency of a two-way information flow for conducting urban plan monitoring involving local citizens. This study presents the development of a prototype of 3D Web GIS for PUPM. This prototype was designed to perform two-way 3D spatial information flows among stakeholders, allowing local citizens to access and contribute 3D spatial information for PUPM. This chapter presents the first attempt to conceptualize the digital triplets concept from 3D RRRs and develop a 3D user interface that enables two-way information flows and 3D web visualization for supporting participatory urban plan monitoring. Digital twins and digital triplets concepts depict the condition of an urban area in a more realistic representation. Local citizens can perform as a 'sensor' for digital twin and digital triplet. This study also considers the ISO 19152:2012 on the Land Administration Domain Model (LADM) and national data governance policy to implement and deploy the prototype on the current National Spatial Information Infrastructure (SII) initiative. The proposed SP Information Package within the LADM revision is used to construct a 3D representation of RRRs from land-use (urban) planning. This prototype is placed as part of the Indonesian national Geoportal for highlighting its capability to handle 3D visualization and two-way information flow.

7.2 Participatory urban plan monitoring in Indonesia

In 2016, the UN member countries adopted the "*New Urban Agenda*," a set of targets for cities to improve their planning practices and urban management for sustainable growth.

UN-Habitat (2015) published "*International Guidelines on Urban and Territorial Planning*" to the UN member countries for organizing urban planning. This guideline recommends the local government "*to set up multi-stakeholder monitoring, evaluation, and accountability mechanisms to transparently evaluate the plans' implementation and provide feedback and information on suitable corrective actions*." According to this guideline, local governments establish a participatory mechanism that facilitates the effective and equitable involvement of stakeholders (including communities, non-government organizations, and businesses) to monitor and evaluate the implementation of urban plans. For this reason, *Bappenas* (2018) updated the Indonesian national urban policy. This policy attempts to handle uncontrolled land and space use and improve the quality of citizens' participation in sustainable development. The local government's inability and lack of citizens' involvement in monitoring, evaluating, and controlling land and space use cause urban sprawls, land disputes, and illegal land use conversions in urban areas (*Bappenas* 2016).

Indonesia's Spatial Planning Act prescribes monitoring the implementation of the urban plan. Further, this Act mentions the "conformance" approach that observes and examines real-world implementations of the urban plans. The Spatial Planning Act allows citizens to monitor, evaluate, and report any Spatial Planning Act violations. The community's role in controlling land (and space) use is regulated in Government Regulations (68/2010) on the Form and Procedure for The Community's Roles in Spatial Planning. This regulation affirms openness as a core principle in monitoring the implementation of the urban plan, particularly by mandating all levels of governments to provide and share relevant data and respond to aspirations (including local knowledge) from local citizens. Specifically, the Spatial Planning Act instructs all government levels to develop and maintain an information system and its dissemination system to monitor, evaluate, and report the implementation of urban plans to society. The roles of the communities in land-use control are shown in Table 7-1. Moreover, this regulation specifies the information that should be provided in such spatial planning information system at the city level, which are: land policies, urban plans, and spatial planning programs that have already, being or will be implemented, as well as informational directives on guidelines, provisions on zoning regulations, permits, incentives, disincentives, and sanctions.

Government Regulation (15/2010) on Implementation of Spatial Planning prescribes a conformance approach in monitoring and evaluating the implementation of urban plans. In 2017, the Ministry of Cadastre and Spatial Planning released a Ministerial Regulation 15/2017 for providing guidelines in monitoring and evaluating spatial planning. This regulation only prescribes general documentation for monitoring and evaluation of the implementation of the urban plan. Although this regulation mentions the procedure for responding to reports from local citizens, it does not explain the role of local citizens in monitoring and evaluation. In the guidelines, monitoring activity is classified into two types: direct and indirect observations. Spatial information is used in both types of observations, while interviews are optional for direct observation. Government Regulation 15/2010 prescribes eight types of violations and eight types of infringements of land (and space) utilization (see Table 2-3). Indrajit et al. (2019) provide workflows for monitoring the implementation of an urban plan in Indonesia based on Government Regulation 15/2010. This workflow includes local government, communities, and non-government organizations as participants in urban plan monitoring. The procedure begins by examining conformity with zoning regulations. In the conformed case, the participant shall examine each zoning's actual function according to the expected function stated in zoning regulation. On the contrary, if participants find actual conditions inconsistent with zoning regulation, they can identify ecosystem threats (including safety, health, and environment). Participants may submit reports to the authority to check the permit's existence and validity over particular land (or space).

Table 7-1. Roles of the communities in land-use control (Spatial Planning Act & Govt Regulation 68/2010)

Roles
1. to provide a suggestion on zoning guidelines and regulation, permit, incentives, and disincentives;
2. to participate in monitoring and evaluating the implementation of an urban plan;
3. to submit a report to authorities in the event of any suspicion of irregularities or violation of land (or space) use following urban plans; and
4. to file an objection to authorities against any development that inconsistent with urban plans.

7.3 Digital triplets for monitoring implementation of an urban plan

In 2014, the International Federation of Surveyors (FIG) launched "*Cadastre 2014 and Beyond*", the updated vision of Cadastre 2014, to advocate the acceleration of registration of the complete legal situations of land and space, including Rights, Restrictions, and Responsibilities (RRRs) (Kaufmann & Steudler 1998 and Steudler 2014). This updated vision also recommends a more robust data management through standardization, data quality assessment, and facilitating sharing of land information. Previously, Enemark (2006) proposes the land management paradigm that cities can implement to manage urban areas (and space) to put into good effect. This paradigm consists of four interacting functions (land tenure, land valuation, land-use planning, and land development) (Figure 7-1 and Table 7-2). This paradigm provides the scope of Cadastre 2014 (Steudler 2014) and recommends cities to standardize land information (Lemmen et al. 2019) and modernize their Land Administration System (LAS) (Enemark 2006).

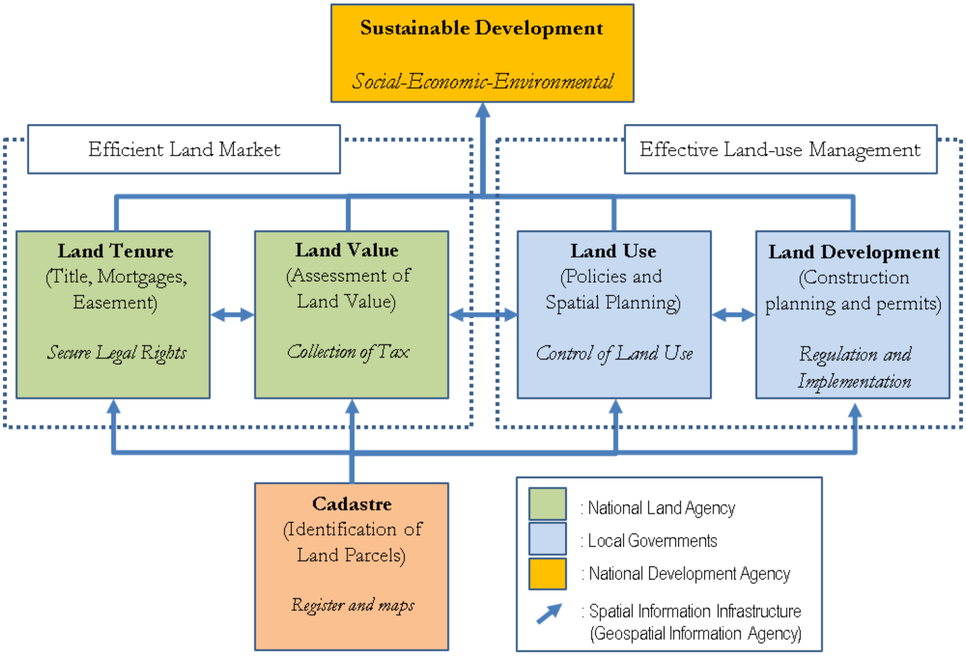

Figure 7-1. Actors and roles in land management and the SII in Indonesia (Enemark & Sevatdal 1999 and Indrajit et al. 2020a)

Table 7-2. Land management functions
(Source: Enemark & Sevatdal 1999).

Cadastre	*the legal surveys to determine parcel boundaries*
Land Tenure	*allocation and security of rights in lands, transfer (sale or lease) of property or use from one party to another, and management and adjudication of doubts and disputes on land rights and parcel boundaries.*
Land Value	*assessment of the value of land and properties (including land or property tax, management, and adjudication of land valuation and taxation disputes.*
Land-use	*determination and control of land use by adopting planning policies and land-use regulations, enforcement of land-use regulations, and management and adjudication of land-use conflicts.*
Land Development	*planning or building new physical infrastructure, implementing construction planning, and changing land use through planning permission and granting permits.*

7

A modern LAS should facilitate land-use control and land development towards effective land-use management. In 2012, ISO published ISO 19152:2012 of the Land Administration Domain Model (LADM) for providing a guideline for countries and cities in establishing or improving their LAS. Many countries implement the LADM to improve data handling and add '*machine-readability*' and '*machine-actionability*' of land information managed in their LAS (Van Oosterom & Lemmen 2015, Kalogianni et al. 2021, and Steudler 2014). Starting in 2019, the LADM is undergoing revision and improvement to modify existing core classes and add packages for land valuation and land-use planning (Lemmen et al. 2019). Accommodating more land management functions means adding more stakeholders to the land administration process. It requires interoperability of information in these functions and makes it available and accessible for land management practices. Cities are recommended to integrate LAS with Spatial Information Infrastructure (SII) for land management as a step forward to make land information accessible to all stakeholders (including authorities, landowners, and economic actors). In the manufacturing domain, Umeda et al. (2019) propose a Digital Triplets concept as an extension of a digital twin to represent engineers' and technicians' knowledge and skill. Digital Triplets aim to support engineers for crating values throughout the product life cycle from physical, digital, and intelligence activity in the industrial field. This chapter attempts to implement a city's digital triples by constructing physical, digital, and legal situations of urban objects (see Figure 7-2).

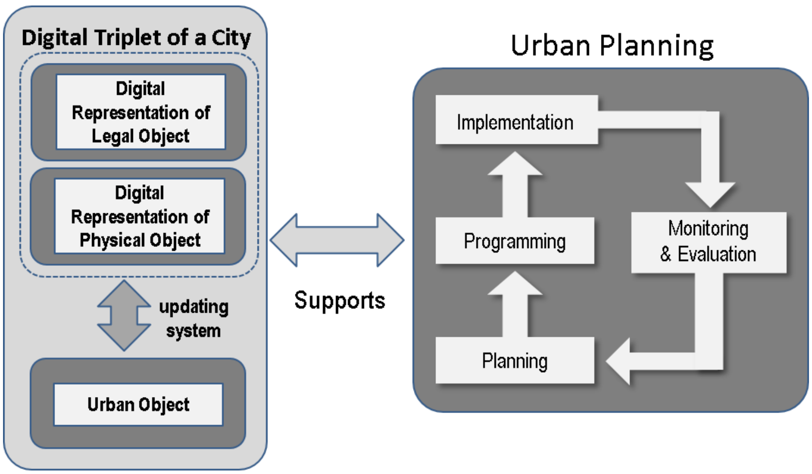

Figure 7-2. Digital Triplet of a City. Adapted from McLoughlin 1969 and Umeda et al. 2019.

7.3.1 Representing 3D RRRs from land-use plan

In 2006, the Committee on Support for Thinking Spatially in the US defined spatial thinking as "*a constructive amalgam of concepts of space, tools of representation, and reasoning processes*" (NRC 2006). The concept of space consists of knowledge, skills, and habits of mind. Spatial thinking enables description, explanation, and discussion of the Spatio-temporal process, including functions, structures, relationships, and operations in a city (NRC 2006). A suitable representation will improve stakeholders' insights and reasoning in presenting activity or phenomena (NRC 1997). The quality of decisions impacting humans and the environment can be achieved through information in higher resolution and dimensions (Kuhn 2005) that provides a more realistic view of a city's complex setting (Roche 2014). Urban planning departments have been widely using 3D city models for the past two decades (Ranzier & Gleixner 1997). These models contain various urban objects (i.e., buildings, trees, roads, pipelines, cables, water bodies). Murata (2004) demonstrates the potential of 3D spatial information for urban planning, such as: to visualize regulations in a complex urban setting, to compare the actual urban objects (e.g., building, public facilities) with regulation, to construct a simulation of the proposed urban development plans, and to facilitate consensus-building between stakeholders.

Frank et al. (2012) highlighted the usefulness of integrating RRRs from private and public laws and the need to have a 3D representation for a complete view of the legal situation of land parcels of urban space. The use of 3D city models is mainly for representing a snapshot of physical objects in urban areas. In comparison, Batty (2018) argues that a city needs to have a digital twin, a digital coupling of a city with a near real-time updating system. The digital twin concept is still emerging. This concept was developed in the manufacturing industry using a 3D model with actual dimensions and location (Grieves 2014). It consists of three parts: the physical object in real space, virtual representation in virtual space, and connecting tools between the physical object and virtual representation. Batty (2018) adopts this concept for cities and expects the birth of other digital couplings to model various abstraction in 3D representation. For example, planners and authorities develop criteria (privileges, prohibitions, and obligations) in the urban plan, translated into Rights, Restrictions, and Responsibilities (RRRs) to 3D space. However, the contemporary land-use plan exploits 2D visualization, while a complex urban setting is better represented in 3D to accommodate criteria constructed in urban planning (Indrajit et al. 2020). The 3D shape of a land-use (urban) plan depends on the regulatory system in a country. The height or depth dimension may be imposed for expected behavior to be performed by all actors in space, including an activity or rights (permission), restrictions (prohibitions), and responsibilities (obligations).

The International Organization for Standardization (ISO) published 19152:2012 on the Land Administration Domain Model (LADM) standard to provide a model-driven architecture and a shared ontology needed by developing an effective cadastral system (Lemmen et al. 2015). The LADM working group is developing the Spatial Plan Information Package (SP Information Package) within the revision of ISO 19152:2012 (Lemmen et al. 2019). This package contains three core classes: *SP_PlanBlock*, *SP_PlanGroup*, and *SP_PlanUnit* (see Indrajit et al. 2020). *SP_PlanBlock* and *SP_PlanUnit* contain geometry and legal expression derived from the land-use (urban) planning process. The LADM standard assigns RRRs information into three subclasses: *LA_Right*, *LA_Restriction*, and *LA_Responsibility* as administrative sources. The current LADM standard also provides *LA_BoundaryFace* class to construct a 3D representation of RRRs (ISO 2012).

Representing Digital Triplets requires more than just geometrical models. They should manage semantic and topological aspects to represent urban objects for thematic queries and further analysis (Gröger et al. 2012). The Open Geospatial Consortium (OGC) published the *CityGML* standard to provide a foundation on geometry, semantics, visualization of objects, and semantics (Kolbe 2009 and Gröger & Plümer 2012). *CityGML* is an open-source database schema that stores objects and attributes in a hierarchical structure using Geography Markup Language (GML). Many cities implement *CityGML* for managing their 3D city models (Biljecki et al. 2015). *CityGML* consists of twelve core modules: *Appearance*, *Bridge*, *Building*, *CityFurniture*, *CityObjectGroup*, *LandUse*, *Relief*, *Transportation*, *Tunnel*, *Vegetation*, *Waterbody*, and *Generics*. This format can only store all objects into a linear geometry structure. These core modules are supported in the 3DCityDB database system (Yao et al. 2018) with many real-life implementations. The 3DCityDB is an open-source database schema and a set of tools to import, manage, analyze, visualize, and export 3D spatial information (Kolbe et al. 2019). In 3DCityDB, a homogenous city object (i.e., building) shall be represented precisely as one object.

Although the *CityGML* standard's initial intention is to manage and exchange 3D city models, it can also publish 3D spatial information on the web. 3DCityDB currently provides several 3D visualization options for users to publish *CityGML* data, such as *Google's KML* (Keyhole Markup Language), *COLLADA*, and *glTF* formats. Publishing or exchanging the 3D city model directly in *CityGML* format is inefficient and requires suitable client-side plug-ins (Ohori et al. 2018). Many web technology options available for cities to publish their 3D spatial information as virtual 3D visualization over the Internet, such as *OpenLayers* 3.0 (www.openlayers.org), *WebGL* Earth (www.webglearth.org), *OpenWebGlobe* (www.github.com/OpenWebGlobe), and Cesium (www.cesium.com). Cesium technology is an open-sourced software that enables users to explore 3D spatial information on a web browser without any installation. Many cities combine *CesiumJS* with 3DCityDb (Yao et al. 2018) for its high-performance, 'mashups' and cross-platform visualization capabilities (Prandi et al. 2015). *CityGML* has a *LandUse* object model representing the 2D surface assigned for planned land use (see Gröger et al.

2012). Digital triplets can be in the form of buildable area (or space), 3D (space) parcels, or 3D mining rights. The granularity of digital twin and digital triplets follows the Level of Detail (LOD) proposed by the Open Geospatial Consortium (OGC). Biljecki (2017) defines LOD as "an indication of how thoroughly a 3D city model has been modeled and as the degree of its adherence to its corresponding subset of reality". LOD is classified into five grades based on visualization, accuracies, and minimal dimensions of objects (OGC 2006). OGC includes LOD types within *CityGML* standards to represent the city's objects in three multidimensional formats.

7.3.2 Updating mechanism: citizens as urban sensors in urban plan monitoring

Today's cities are using spatial information for various applications and analyses. Moreover, Geo-ICT is proven to improve society's ability to plan and manage urban areas and making a city smarter (Batty et al. 2012, Daniel & Doran 2013 and Roche 2014). 3D representation and Geo-ICT and its combination are considered as enablement to open ample opportunities for cities to manage their land (and space) (LeGates et al. 2009 and Batty 2018). If this combination is shared with relevant stakeholders, it will improve the spatial thinking and cognitive ability needed to plan and manage a city (Roche 2014 & 2017). Since the last decade, citizens' ability to use spatial representation to monitor their livelihoods improves (Arsanjani et al. 2015, Crooks et al. 2015, and Herfort et al. 2019). In 2007, Michael Goodchild introduced "*citizens as sensors*" terminology for an alternative source of mapping. Participatory mapping gains popularity among local citizens in many countries, facilitating their local knowledge of a map (Goodchild 2007). They are provided with reference maps (or imagery) and tools to contribute spatial information to the participatory urban monitoring system.

Minang & McCall (2006) define Local Spatial Knowledge (LSK) as local knowledge generated by local citizens that offering a unique description of land or space. In 2008, Sarah Elwood stressed that citizens require land information to contribute local knowledge (Elwood 2008). In the participatory approach, sharing (land) information to all participants would be the foundation of a participatory approach and influential to the quality of participation contributed to the initiative (Arnstein 1969 and Wilcox 1994). Later, Goodchild (2009) introduced the term "*Neogeography*" for alternate map-producing techniques from crowdsources, contributors other than experts, and professionals. He classified Volunteered Geographic Information (VGI) as maps produced from *Neogeographers* using advanced Geo-ICT innovations, such as mobile mappers and unmanned aerial mapping systems. There are success stories of cities organizing a facilitated VGI, using web mapping interfaces to allow local citizens, individually or in groups, to contribute local knowledge in the form of a map with a predefined set of criteria to a specific geographical extent (see Seeger 2008). Local citizens are the custodian of Local Spatial Knowledge (LSK) as they hold local knowledge of physical objects or phenomena that scientist and professionals do not (McCall & Dunn 2011). However, they need certain spatial information used as reference and tools to contribute their LSK on maps for maintaining preciseness, including in Participatory Urban Plan Monitoring (PUPM). Therefore, the existing SII should be improved to enable two-way information flow among stakeholders and manage and disseminate multidimensional spatial information. This chapter presents the development of a user interface built on an open spatial data sharing for PUPM using the proposed SP Information Package of the LADM revision.

In participatory urban plan monitoring, the quality of information flows should be carefully designed and managed. This chapter follows the quality of the information flows concept proposed by Gudowsky & Berthold (2013) for developing open participation in the SII. The concept of quality of information flows is classified into four classes: one-way and two-ways, depending on the recipient's understanding, media, and timing of the data. The one-way flow consists of uni-directional and bi-directional dimensions. The one-way information flow among stakeholders can be found in most SII, where topographic maps are published as open data to a broader community. *Uni-directional* is the most commonly used in sharing the map with no right for citizens to negotiate. Simultaneously, the *bi-directional* flow is two reciprocal uni-directional flows without the obligation to consider information from the other side. In contrast, a two-way flow has two types: *discussion* and *dialog* (Gudowsky & Berthold 2013). *Discussion* allows spatial information sharing to meet a consensus through arguments or constructive disagreement. *Dialog* enables stakeholders to experience the free flow of information to improve understanding of the specific topic. Open participation requires two-way flows where information exchange has more intensity between stakeholders in *discussion* or *dialog*.

7.4 Constructing 3D urban plan for Indonesian cities

In the Indonesian regulatory system, urban areas are divided into zones of spatial designation depicted in the urban plan map. Local governments use zoning regulations to ensure quality land or space functions, minimize unintended land or space utilization, and preserve the environment. Specific restrictions and responsibilities are imposed in each zone to regulate location, activities, land-use intensity, and building code. Land-use (urban) plans are used as a reference for controlling land or space utilization, granting land or space utilization permits (including air and underground utilization rights developments), determining incentives, imposing sanctions, and providing technical guidance in urban development. The spatial Planning Act commands Indonesian cities to develop zoning regulations for determining basic rules and techniques for zoning arrangements.

Basic rules constitute requirements for spatial use, including conditions for activities, land use criteria, land-use intensity, building codes, provision of necessary infrastructure and public facilities, special regulations, technical standards, and implementation guidelines. The Techniques for Zoning Regulation (TZR) were implemented in Indonesian cities to allow flexibility in applying zoning rules. TZR is also helpful in overcoming various problems in implementing necessary zoning regulations, considering the contextual conditions of the area and the direction of spatial planning (Ministry of Cadastre and Spatial Planning Regulation 2018). TZR consists of *Transfer Development Right* (TDR), *Zoning Bonus*, *Conditional Uses*, *Performance Zone*, *Fiscal Zone*, *Development Agreement*, *Overlay*, *Threshold Zone*, *Flood Zone*, *Special TZR*, *Growth Control*, and *Preservation of Cultural Heritage*. The Ministerial or technical regulations are also considering multiple aspects for height limitation. For example, the Minister of Cadastre and Spatial Planning Regulation (2018) provides a guideline on setting the limit of the height of high-density vertical housing areas to 40 meters. While for landed high-density housing areas, it is only 10 meters allowed by this regulation. It is measured from the ground to the maximum distance of the roof. For other zoning types, authorities apply the height limitation (*H_BuildingEnvelope*) for each lot, depending on its zoning type. It considers Air Safety Operation (ASO), Fire hazards (F), Property's optimal prices (P), Floor Area Ratio (FAR), Land Use Intensity (LUI), Sky Exposure Plane (SEP), Angle of Light (AOL), Wind speed (WS), Earthquake (EQ), and Transportation (T). Thus, the third dimension of a building envelope can be determined as follow:

$$H_{BuildingEnvelope} = f(ASO, F, P, FAR, LUI, SEP, AOL, WS, EQ, T)$$

On the type of land function, each allotment contains a set of zoning requirements. These requirements may be represented with a 3D RRRs object with dimensional requirements (i.e., maximum building heights, ground-floor area coefficient, total-floor area coefficient, free distance limit, and borderline distances).

7

7.5 A web application for participatory urban plan monitoring

In 2020, the Indonesian parliament passed the *Cipta Kerja* (Job Creation) Act, often called the Omnibus Law. 3D cadastre is included and highlighted in this Act by assigning rights for *Hak Guna Bangunan* (rights to utilize construction), *Hak Pakai* (rights to use), or *Hak Pengelolaan* (rights to manage) in space above, on, or below the surface. The Job Creation Act transforms RRRs from 2D to 3D representation by specifying land use below, on, or above the surface and governing rights of access for utilities (i.e., cables) over or below land or space. The volumetric (height and depth) limitation of land rights (rights of space) is introduced explicitly by including maximum building heights, ground-floor area coefficient, total-floor area coefficient, free distance limit, and borderline distances into

3D RRRs. Moreover, this Act puts more burden on an urban plan as it accommodates environment impact assessment and building code into *Rencana Detil Tata Ruang* (RDTR) (detailed urban plan).

Consequently, Indonesian cities need to develop 3D RRRs consisting of the four functions of land management (land tenure and cadastre, land value, land-use, and land development, see Enemark 2006). In 2018, GOI launched the Online Single Submission (OSS), an online platform connecting various sectors to issue permits and business licensing and investment at all government levels (Ministry of Trade 2018). The OSS functions as a single national gateway for issuing permits and business licensing. Therefore, 3D RRRs should be the core data in a permit system, such as the OSS. The spatial plan information package from the revision of ISO 19152:2012 has the potential to provide a foundation for standardizing urban plan information and zoning regulations to be used for the OSS. New guidelines for implementing technical aspects of the Spatial Planning Act are provided by the Ministry of Cadastre and Spatial Planning Ministerial Regulation 14/2020 on Guidelines on Development of Spatial Planning Database (DSPD). The ministerial regulation contains guidelines on DSPD to ensure information interoperability and consistency of the land-use plan. It provides standardization of the spatial plan feature class, including format, storage structure, the naming convention for a spatial plan, and a detailed spatial plan (urban plan). This guideline mentions geometric aspects in limited aspects, covering 1D (point) and 2D (line and polygon) primitives. It still has not provided 3D primitives that regulations and smart cities demand.

7.5.1 Workflow for Participatory Urban Plan Monitoring (PUPM) application

Based on Government Regulation (68/2010) on the Form and Procedure for the Community's Roles in Spatial Planning, this study develops a workflow that allows citizens to participate in urban plan monitoring. The workflow determined roles for performing tasks stated in Table 7-3: End-Users, Contributors, Contributors-Geometry, and Validators. This workflow enables all types of stakeholders to perform roles assigned for participatory urban plan monitoring. This study uses the existing urban plans of Jakarta and Bandung City that implement height (and depth) thresholds to construct a volumetric form of 3D RRRs. This study also includes 3D city models of these cities to improve the spatial thinking of all stakeholders. With 3D RRRs and 3D city models, the PUPM application constructs digital twin and digital triplets of Jakarta and Bandung and enables all stakeholders to virtually monitor urban plans. The PUPM application can be accessed through https://tanahair.indonesia.go.id/pupm. This study constructs PUPM workflow to enable two-way information flow, facilitating data collection and consensus-building between contributors and validators to collect and verify LSK on implementing the urban plan. This activity can be attained through (1) accessing 3D city models (digital twin) and 3D RRRs (digital triplets), (2) comparing actual conditions with 3D RRRs by updating land (or space) functions, and (3) modifying the existing 3D city models with updated (and more realistic) records with multimedia files (Figure 7-3).

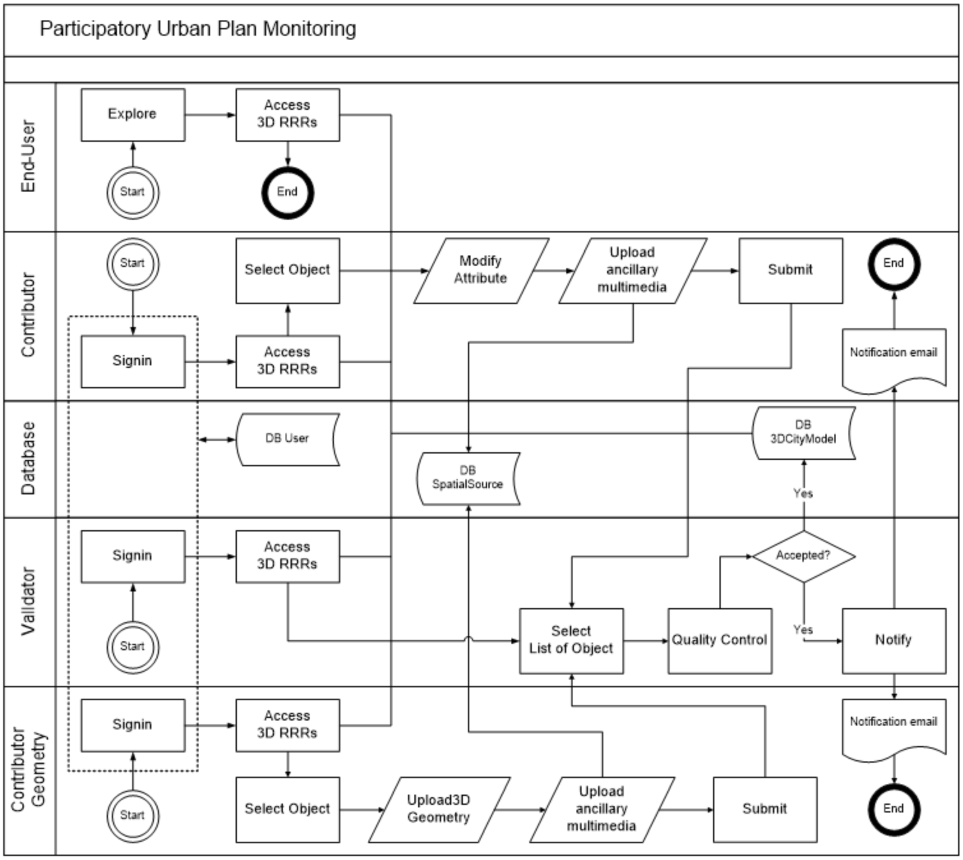

Figure 7-3. The workflow of the PUPM application

Table 7-3. Roles and privileges in participatory urban plan monitoring

Roles	Access	Generate/update		Validate
		attribute	maps	
end-users	☑			
contributor (attribute)	☑	☑		
contributor geometry	☑	☑	☑	
validator	☑	☑	☑	☑

The PUPM application involves four roles in urban plan monitoring: contributor geometry, validator, database, contributor (attribute), and end-users (see Table 7-3). The four roles determined in this study are to accommodate the roles prescribed on Government regulation (68/2010). Contributors and geometric contributors can modify attributes and upload a 3D file with a multimedia file as a supporting confirmation. Both contributors then submit these files to the PUPM system. A web-based application was developed to support monitoring the implementation of an urban plan that allows participants to access 3D urban plans and contribute 3D building with land (or space) actual utilization. The workflow is using the "conformance" approach that compares actual conditions with urban plans. Local citizens may follow the workflow to monitor and report the urban plan infringements.

7.5.2 The spatial database for 3D RRRs from urban plans

Urban plan in Indonesia is governed by public law that consists of Rights, Restrictions, and Responsibilities (RRRs) prescribed in a zoning regulation for each zone. Currently, Jakarta and Bandung are still managing urban planning with 2D representation and not complying with the newly enacted guideline from the Ministry of Spatial Planning Regulation (2020). On the other hand, the Job Creation Act requires 4D topology, a 3D geometric representation with temporal managed as an attribute of urban plans to support the permit system. The OSS system also prescribes standardization to ensure *machine-readability* and *machine-actionability* for all data, including urban plans. However, Jakarta and Bandung have not standardized their urban plan according to current national or international standards. Therefore, this study includes construction 3D representation and information interoperability to comply with the newly enacted guideline from the Ministry of Spatial Planning Regulation (2020) for Jakarta and Bandung's urban plans and the proposed SP Information Package of the LADM. This study includes versioning capability to urban plan database to enable comparison or monitoring and evaluation tasks in participatory urban plan monitoring. The height dimension is sourced from the zoning regulation or 'building envelope' of each zone. The height value is computed and enforced by local governments using algorithm 1 in Section 7.4. This study implements the SP Information Package as part of the revision of ISO 19152 on the LADM for ensuring interoperability between land management information, specifically *SP_PlanUnit* and *SP_PlanBlock* classes and its code lists. The core LADM data models and code lists are applied to manage common land management information. *LA_BoundaryFace* class of the LADM was used to construct a 3D representation of urban plans for Jakarta and Bandung City. Implementing the SP Information Package on Jakarta and Bandung urban plans could be done smoothly. These maps contain height limitation parameters and have sufficient quality in geometric, logical consistency, and semantics. These urban plans are developed upon large-scale topographic maps (1:1000 and 1:5000) but apply their semantics standards.

The 3D spatial representation of urban plans is transformed into *CityGML* standards using *Feature Manipulation Engine* (FME)® of *Safe Software* before being loaded into the *3DCityDB* database. Two actual urban plans of Jakarta and Bandung city are stored in 3DCityDB in CityGML format to support the PUPM application. These urban plans are then converted to a 3D tileset using a '*batched 3D model*' (*b3dm*) format for faster interaction at the client side. The PUPM application prototype provides a minimal topography map published from global map services for adding locational context and spatial references for its users. The 3D database was designed to allow contributors to upload their building data. This study applies a non-linear geometry to comply with all possible shapes commonly formed to polygons in urban plans. For representing an urban lot in 3D, this study selects *gml:MultiSurface* due to irregular surfaces. *CityGML* standard provides a minimalist option for an urban plan in three types of attributes: class, function, and usage. LOD1 was used to represent 3D urban plans in Jakarta and Bandung cities with semantic standards follow the SP Information Package of the LADM revision. The PUPM application is supported by a 3D spatial database using PostgreSQL and structured following the *3DCityDB* version 4.20 (Figure 7-4).

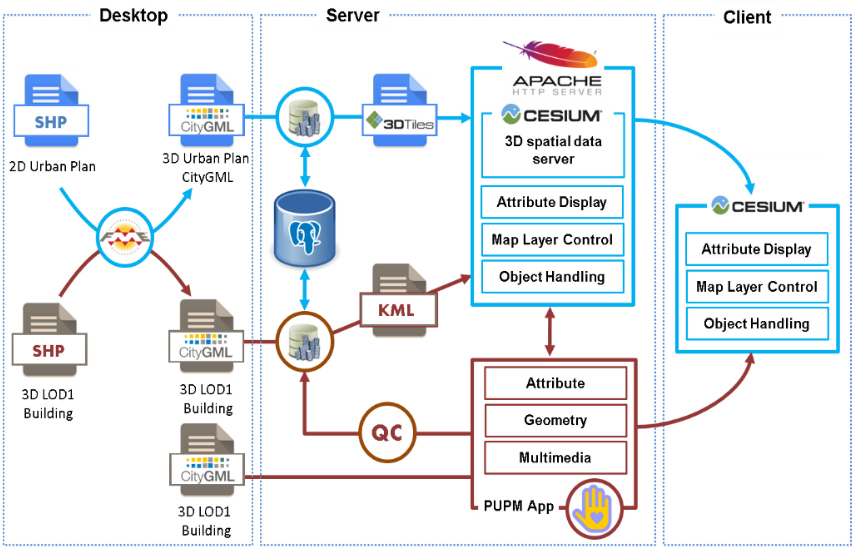

Figure 7-4. Configuration of 3D Database and 3D Visualization of PUPM

Temporal information is managed as *VersionedObject* to document change over time. The standardized spatial database aims to maintain and preserve data integrity, appoint authorized data custodians, provide 3D RRRs and building data to users using a common data model (LADM) in a simplified way, and ensure interoperability for urban plans in a federated system. However, this study only provides a basic form but representative for exposing the LADM standard and 3D RRRs derived from the urban planning process for participatory urban plan monitoring. *CityGML* was used for its capability to support wide ranges of 3D geometry with temporal information managed as an attribute.

7.5.3 The PUPM application prototype

The PUPM application (beta version) facilitates local citizens' participation in the urban planning process by providing participatory urban plan monitoring tools. This application is developed through web 2.0 technology to optimize outreach to local citizens with minimal barriers. This study develops a 3D spatial database capable of managing the OGC's *CityGML* standards. The *3DCityDB* was installed in *PostgreSQL* to store and manage *CityGML* data for digital twins (buildings) and digital triplets (urban plans). An overview of the server-client architecture is presented in Figure 7-4. The server-side consists of a 3D spatial database, Geospatial Content Server (GCS), and a web-based user interface. The *3DCityDB* is used for managing 3D building data and 3D urban plan, while *CesiumJS* server-side publish these data in 3D visualization. The PUPM application is installed as part of the Indonesian Geoportal and can be accessed openly through http://tanahair.Indonesia.go.id/pupm.

a) Accessing 3D urban plan

This application offers standard capability provided by *CesiumJS* ™, an open-source platform for delivering 3D spatial information. *CesiumJS* is an open and free software to disseminate 3D spatial information without installing anything on the users' side. Cemellini et al. (2018) highlighted that *CesiumJS* could provide navigation, hovering tooltip, mashing-up with multiple layers, transparent coloring and highlighting, searching and querying 3D objects, and advance viewing. The PUPM application uses caching and 3D tiling techniques to communicate between the server and the client sides when opening and exploring the area. It visualizes RRRs in 3D from a spatial database following the LADM standard on the server-side (see Figure 7-5 & Figure 7-6). At the client-side, a user interface based on *WebGL* was developed for users for visualizing, querying, interacting, and submitting 3D spatial information in participatory urban plan monitoring.

Based on surveys and interviews conducted in 2017 and 2019, stakeholders preferred a volumetric shape of the urban plan to represent the building envelope and 3D RRRs. However, it will need a high-quality Digital Terrain Model (DTM) comparable to at least LOD1 or at a map scale of 1:1000. This terrain data will be used as a height reference for 3D spatial information (building and 3D RRRs). As online terrain data is only available at a medium or smaller scale (less than 1:25,000), this study regards all spatial information in zero elevation (flat earth surface) to avoid misrepresenting the building's height and building envelope.

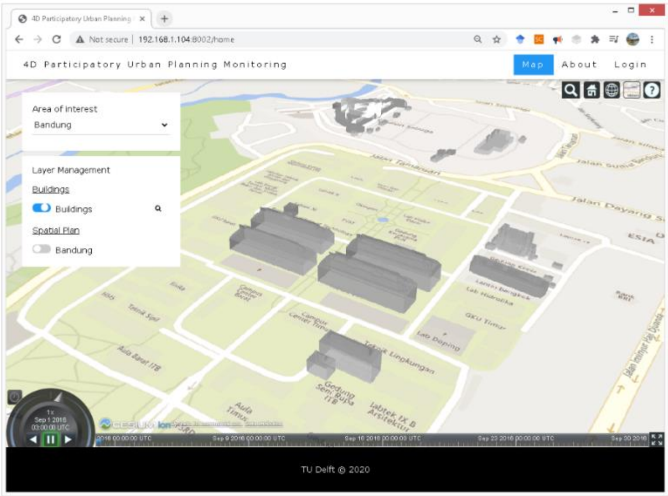

Figure 7-5. Overview of Digital twin (3D city model) for the end-user interface
Location is Institute Technology of Bandung Campus at Bandung City, Indonesia

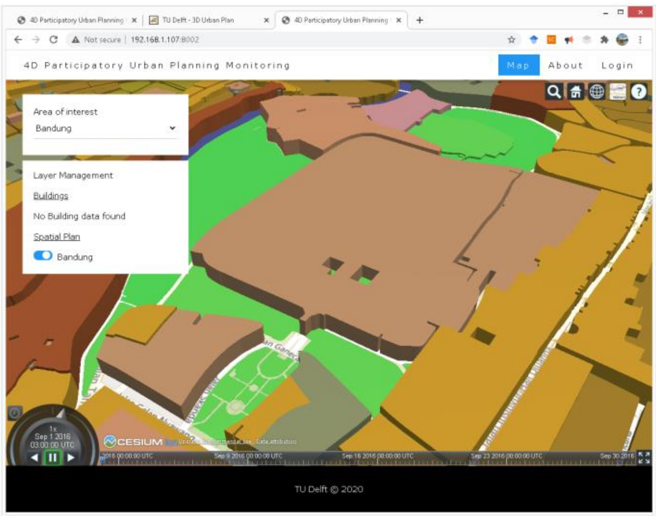

Figure 7-6. Overview of Digital triplets for the end-user interface
Location is Institute Technology of Bandung Campus at Bandung City, Indonesia

b) Contributing and updating 3D building information

The PUPM application facilitates users to interact with 3D urban plans of Jakarta and Bandung City. A custom-made python script is used to enable automatic loading of *CityGML* files containing 3D building into *3DCityDB*. This study also enables automatic quality control provided by *3DCityDB* to validate attributes and geometries before updating the database. The PUPM prototype is also converting the newly submitted to KML format. 3D tileset (KML) contains building information and urban plan contributed by all stakeholders. The PUPM preserves information from users and is validated by the authority as a versioned object for temporal information. The temporal data will allow 3D land-use change analysis, which is planned to be developed in the next version of PUPM. This study provides 3D building in LOD-1 and LOD-2 for one district in Jakarta and two districts in Bandung City in gml:Multisolid format for the initial implementation. This format allows users to query a building in city-wide data. Users are also provided five sets of buildings in *CityGML* format to contribute 3D spatial information into the PUPM system.

c) Validating contributed 3D building data

In an exemplary implementation, PUPM shall use ISO 19157:2013 on Data Quality to examine both geometries and attribute data submitted into the system. However, the PUPM version 1.0 only examines the Logical Consistency of data submitted by contributors. This functionality is part of the *3DCityDB* importing and exporting tool operating in batch mode triggered by the validator role. This tool is configured to detect and validate XML data containing 3D buildings in LOD 1, LOD2, and LOD3. Validators may use their desktop-based software for assessing other data quality elements prescribed in ISO 19157:2013 (i.e., Completeness, Positional Accuracy, Temporal Quality, and Usability Elements). There is free and open-source software available for examining data quality elements available for validators and users to convert or asses data in *CityGML* format (http://www.citygmlwiki.org/index.php/Freeware).

7

7.5.4 Integration of participatory urban plan monitoring into the smart city system

The Open Geospatial Consortium (OGC) recommends Web Service Framework (WSF) to add spatial enablement into the smart city system. This framework facilitates users to discover, browse, and query metadata and bind spatial information (and metadata) services (Percivall et al. 2011). The WSF also anticipates the integration of spatial sensors and systems into smart city ecosystems. However, Indonesia's smart cities are in the initial phase and have not complied with the OGC framework. As discussed in Section 2.2, the Open SII can provide a supportive environment for more stakeholders to access and share spatial data in a smart city, particularly local citizens. The PUPM application facilitates local citizens to access 3D spatial data for monitoring the implementation of an urban plan in their neighborhood. The OGC WSF provides system architecture for spatial data sharing mechanisms in distributed databases and sensor networks (see Figure C-1 in Appendix C). This architecture implements four Service-oriented Architecture layers (SoA): Sensing, Data, Business, and Application layers. The development of PUPM acknowledges the OGC's Web Service Framework to further integrate with the smart city system. The PUPM application is suitable for data and application layers to manage urban information differently from various sources and the semantic 3D city models.

The data layer facilitates data ingestions, quality assessments, and dissemination. Open standards in establishing the Open SII will ensure interoperability in connecting information services with minimal or no cost. The OGC Web Services Framework for Enterprise Component of Smart City was discussed and agreed upon to be used as a reference by representatives from the Government of Jakarta and Bandung. These cities will support such standardization to better capture urban phenomena and infrastructure conditions and allow third parties to provide interactive tools to contribute information to the city. The PUPM application and spatial database were developed following ISO and OGC standards to integrate into any data ecosystem using similar standards. This application aims to manage, preserve, and share 2D and 3D urban plans as versioned objects. However, the PUPM is designed to record changes, including the person who proposes and validates them. In summary, there is significant importance that local government can use PUPM application to gather 3D building and attribute from local citizens and business. This study covers urban plans for the two biggest cities in Indonesia (Jakarta and Bandung) to illustrate the realistic condition of such a system. Getting 3D spatial information for urban planning is more complicated since it needs an accurate DTM as a reference for buildings and urban plan data.

7.6 Usability Analysis

The purpose of usability analysis is to help developers to improve the PUPM application. ISO 9241-11:2018 defines usability as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*." Usability testing is intended to gauge how the PUPM application will be used by a broad range of users with different knowledge and skills in utilizing Geo-ICT. The usability test attempts to resemble reality but not the actual situation. ISO 9241-11 prescribes usability testing to measure three attributes: effectiveness, efficiency, and user satisfaction. However, this study only applies informal usability testing, as Nielsen (1994) highlighted to gauge effectiveness, efficiency, and user satisfaction.

a) Preparation

The usability test was performed in October 2020 in an online form with explanation and assistance through a virtual meeting. The questionnaire was designed specifically for individuals with Local Spatial Knowledge (LSK) of a selected site. This study selected the Institute Technology campus for usability testing, and the participating students were considered '*local citizens*.' The questionnaire asked respondents to simulate how local citizens contribute LSK to the PUPM application. Forty-nine respondents participated in a usability test; see Figure 7-7. The respondents performed all tasks of four roles prescribed in the questionnaire. This study assigns respondents to the type of stakeholders (see Table 7-4).

Table 7-4. Respondents and type of stakeholders

Respondents	**Potential type of stakeholders**
Visitor	NEO
Undergraduate & Graduate Students	
▪ Geodesy or Geomatics	EAUTH, EPRO, EAMT, IAMT
▪ Architecture	EAMT, IAMT
▪ Urban Planning	EAUTH, EPRO, EAMT, IAMT
▪ Civil Engineering	EAMT, IAMT

7

b) Assessing effectiveness and efficiency

This study implements a post-release assessment using on-site testing to evaluate the effectiveness of the PUPM application in the user's environment for improvement. In this approach, developers invite users to perform several tasks, evaluate and validate the usability (Barnum 2011, pp 81-82). The usability test started with a brief description of the PUPM application. The respondents had to explore all functionality by themselves and relate to the sections in the questionnaire.

This study gave respondents six tasks via an online meeting application to assess the effectiveness and efficiency of the PUPM application. The first task is to make the user familiar with functionalities. Task 2 aims to provide experience with multidimensional representation. The third task requested respondents to use provided tools to update buildings' characteristics, including the type of land use, building height, and recent pictures. These tasks were explicitly designed for respondents familiar with the test site (ITB campus) and to let them experience four roles in the PUPM application via online form. The questionnaire contains a straightforward explanation for each task and can be used as a guideline for completing tasks. In the usability test, 49 respondents representing three groups are expected to assess the effectiveness of the PUPM application. The questionnaire was performed during lockdown time, so most respondents used home internet facilities or mobile tethering devices. Almost all respondents are young people under 30 (48 out of 49), and 63.3% female. The distribution of age of respondents is within the range of two major classes of social media users in Indonesia (Statista 2021). Seeing 3D urban plans will be the first time for all respondents, and more than 75% of respondents were self-declared to have sufficient knowledge and GIS skills (score seven and above). However, almost half of the respondents assessed themselves as having less knowledge and skill in 3D spatial data and 3D visualization.

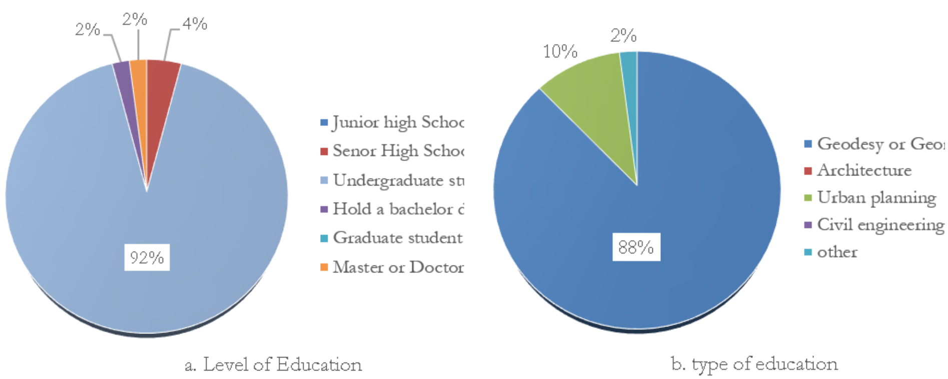

Figure 7-7. Characteristics of Respondents

Table 7-5. Six tasks for assessing the PUPM application

Task 1:	to get familiar with the functionality, including the type of users, buttons (pan, zoom, and other control), and process
Task 2:	to understand 3D urban plans and 3D building information
Task 3	to contribute or update attribute of a building (including photo and video) in two-way flows
Task 4:	to contribute new 3D building data in two-way flows
Task 5:	to see the history of changes in a building
Task 6:	to validate submitted data

There is only 57.8% of respondents were aware of the importance of the 3D urban plan. All respondents are familiar with the location (ITB campus), with 92% working or studying at the location (42 respondents from the geodesy and geomatics department). From the questionnaire, the PUPM application was proven to enable users to perform given tasks (see Table 7-5) for accessing and contributing 3D spatial information for monitoring the implementation of urban plans. Most of the respondents (75.5%) succeeded in using navigation tools to locate a point and prove relative position through the screen with the standard tool provided by Cesium viewer. However, some respondents (33%) cast low scores (six or below) on smoothness or unresponsive screens on their laptops at home.

c) User's satisfaction

The respondents reported some delays due to slow internet connection performance with big-sized data transfer, particularly on loading 3D urban plans for the whole city. The PUPM requires a high-speed Internet connection, which the home internet infrastructure in Indonesian cities is still lacking. However, they cast high grades (85%) on tools for navigating on-screen. More than half (56%) of respondents still had difficulty identifying height violations of the urban plan visually. The respondents score only average grades for updating attributes (average grade 5 of 10) and contributing 3D building data (average grade 5), which did not satisfy many portions of respondents' demand. The PUPM application was valued slightly better (average grade) to provide urban plans access in 3D representation and buildings' historical data. The problem encountered by the PUPM application was mostly about slow responses accessed from respondents' home internet devices. It would be expected to improve 3D data delivery through slower internet access to gain more users' satisfaction.

7.7 Conclusions and Future Research

7.7.1 Conclusion

The exploitation of 3D representation for land management is considered beneficial to improve spatial thinking and monitor and evaluate the implementation of the urban plan. Compared to the 2D visualization, Representing Rights, Restrictions, and Responsibilities (RRRs) using digital format over the two biggest Indonesian cities' internet seem to leverage the discussion toward monitoring and evaluation targets easier. The PUPM application can minimize unnecessary debates (or even conflict) caused by the interpretation of physical characteristics of a violation of urban plan and creating more time to explore solution creation. The spatially enabled government and society were determined in continuous improvements for Indonesia's smart city project. The Indonesian government declared a clear and well-defined action plan for developing a 3D urban plan to accompany the 3D cadastre as mandated in the recently enacted Job Creation Act (2020). Jakarta and Bandung City's government needs to develop digital triplets for representing the legal object to accompany digital twin (for physical objects) in their smart city system. In contrast, the BPN (national land agency) and its city branches should establish similar land administration capability and support the OSS system for granting location permits to economic actors throughout nations. All of the user interfaces of the PUPM application were functioned in order and highlighted in the development phase, and usability analysis are:

i. Standardization will ensure information interoperability in land tenure, land valuation, land-use planning, and land development planning.
ii. The web application may be suitable for maximizing outreach. However, the performance of the system for exchanging 3D data over the internet may cost speed for maximizing the functionality of user interfaces.
iii. 3D spatial representation enables users to identify dimensional compliance of building with urban plans.
iv. A two-way direction was successfully facilitated by the PUPM application to monitor the implementation of the urban plan. However, this application has gaps to improve, mainly optimizing 3D data delivery to the potential contributors with minimal internet access.

7.7.2 Future Research

As mandated by the spatial planning regulations, local governments in Indonesia must develop a GIS for Spatial Planning (GISTARU) to support the spatial planning process. Making 3D urban plans accessible may add more attention to participants to contribute to the GISTARU to present the actual condition with more realistic visualizations. This study may stimulate more research for:

a) Improvement of Geo-ICT facility for supporting 3D data delivery.

Disseminating and contributing 2D spatial information requires a sophisticated ICT infrastructure and systems, let alone 3D data. In the digital transformation era, where most data transfer is through the Internet, a smart city should consider 3D data delivery of its ICT infrastructure. There is an urgent need to study the integration of the Open SII with the smart city ecosystem capable of delivering digital twin (to represent physical objects) and digital triplets (representing legal objects) to society helps add spatial enablement of a city.

b) Building information models for smart cities.

BIM stands for Building Information Modelling and is a 3D model-based process used across the building design and construction process to efficiently design buildings and plan every stage of building. The use of BIM technology in construction project management is increasing in the last decades. 3D models from BIM can be utilized for data input of the PUPM application. However, managing and disseminating BIM for the whole city requires heavy computing and fast internet capability. Therefore, this study proposes integration of BIM and CityGML technologies that capable to manage the whole cities.

c) Standardization of four functions of land management.

Interoperability is vital for information integration, including for participatory monitoring of the implementation of the urban plan. In Indonesia's two biggest cities (Jakarta and Bandung), 3D representation of RRRs is also essential for land development planning, particularly for urban planning and monitoring and granting businesses and investment permits. It is expected to find a better solution to improve digital triplets that contain a complete view of the legal situation for land parcels and urban space. Therefore, this study proposes research on managing and visualizing a complete and up-to-date view of legal situation of land parcel and urban space with 3D representation.

d) Development of 3D visualization capability for a smart city.

A smart city must consider the representation of its physical (digital twins) and legal (digital triplets) objects, not only for improving the city's income (i.e., taxation) and social protection (i.e., disaster management), but also for monitoring and evaluating its urban plan performance and enforcement. In a complex urban setting, land (and space) management are often involving activities below and above the ground. The 3D representation for physical and legal aspects is needed for cities in policy- and decision-making processes to regulate and manage Rights, Restrictions, and Restrictions (RRR) of urban spaces. Therefore, more research on 3D RRRs for smart cities covering objects below, on, and above the surface is required. This study opens opportunities for a comprehensive framework for developing, maintaining, and sharing digital twin and digital triplets for smart cities.

8
Conclusion and Recommendations

This final chapter summarizes the outputs and outcomes of the dissertation. Section 8.1 consists of the answers to the main research question and sub-questions guiding the overall study. Further reflection on the conclusions is presented in Section 8.2. The scientific and societal contributions of this research are provided, along with the limitations of the research. Finally, recommendations for further development are presented to improve local citizens roles using spatial information for managing their livelihood and apply the result to potential applications in the field of land management.

8.1 Introduction

The progress in geoinformation, open data, and spatial data sharing research are vital in participatory urban plan monitoring by delivering digital representation to stakeholders to contribute urban information as factual as possible. This study was built upon the land management paradigm. Its functions (land tenure, land valuation, land-use planning, and land development) are managed in a modernized Land Administration System (LAS). The interaction between these functions is essential for cities in managing their urban areas, particularly in participatory urban plan monitoring. Citizens have valuable Local Spatial Knowledge (LSK) about their neighborhood. A city should harness LSK for monitoring and evaluating the implementation of the urban plan. The ability of local citizens to contribute their LSK to their cities should be strengthened, for example, by making land information interoperable across land management functions and allowing two-way information flows between citizens and authorities in urban planning. This chapter answers the research question and sub-questions based on three critical and interrelated aspects discussed in the previous chapters: information interoperability, 4D (3D and time) representation of legal objects from urban planning, and open spatial data sharing.

8.2 Answer to the research question

8.2.1 Answer to main research questions

This dissertation aimed to design and implement the open spatial information infrastructure for 4D participatory urban plan monitoring. Based on the objective, this study determined the main research question and four research sub-questions. The main research question is:

"How to design and implement The Open Spatial Information Infrastructure for 4D Participatory Urban Plan Monitoring?"

The main question sought to answer how to design participatory urban plan monitoring using 4D spatial information with temporal data managed on an Open Spatial Information Infrastructure (SII) in Indonesian cities. This research proposes four steps for cities to implement the Open SII to support Participatory Urban Plan Monitoring (PUPM).

Step 1: *Assess the type and specification of spatial information*

All stakeholders can benefit from properly selected spatial information and interoperable urban plans in monitoring the implementation of urban plans. This research proposes a novel approach for selecting spatial information necessary for urban planning purposes, considering three chains: regulation, functional, and user-centered aspects. The local government can use the selection method for allocating resources to provide spatial information for PUPM. The selection process should consider the improvement of the spatial thinking of all stakeholders.

Step 2: *Construct interoperability and comparability of spatial information*

Using urban plans in a standardized format is crucial for ensuring information integrity and interoperability for further reuse of information, particularly for comparing land development with urban plans. The proposed Spatial Plan Information Package (SP Information Package) in the revision of ISO 19152 on the Land Administration Domain (LADM) offers a robust standardization and interrelated with other land administration classes, providing a more complete view of the legal situation of land and urban space. The SP Information Package provides a conceptual model to document information of Rights, Restrictions, and Responsibilities (RRRs) from urban planning and land development processes. The SP Information Package is integrated with the LADM classes for allowing information integration from land management functions (land tenure, land valuation, land-use planning, and land development). A multidimensional representation and temporal aspects should be constructed and managed to better visualize RRRs for land parcels and urban space for PUPM. This study proposes digital triplets representing 3D RRRs (legal objects) with updating system to accompany digital twin (physical object) for PUPM.

Step 3: *Construct The Open SII at the city level*

Improvement on the accessibility of relevant spatial datasets is required for enabling all stakeholders, particularly local citizens, to perform urban plan monitoring. Spatial information selected from step 1 should be shared with all stakeholders and promote it as a '*Common Operating Map*' (COM) to avoid information asymmetry in monitoring the implementation of the urban plan. Further, all stakeholders should become a sensor of the city for updating COM to represent the actual situation of the urban area. Therefore, cities should make their open spatial data sharing capable of performing two-way information flow to ensure co-production of urban information. This study integrates open data and open participation principles into the SII concept to establish Open Spatial Information Infrastructure (SII). All stakeholders can be data producers in Open SII, but validation and verification should be the task of authorities.

Step 4: *Develop tools for PUPM on The Open SII platform*

The exploitation of Geospatial Information Communication Technology (Geo-ICT) for PUPM is vital to improving outreach to broader stakeholders and preserving information interoperability and integrity. The PUPM application should deliver and share 3D spatial data for representing physical (digital twin) and legal objects (digital triplet).

8.2.2 Answer to research sub-questions

Research sub-question 1 – *What type of spatial information is necessary for supporting participatory urban plan monitoring in Indonesian cities?*

This study proposed three chains of requirement approaches to determine spatial information needed for participatory urban plan monitoring. The first chain contains regulatory requirements that are enacted and enforced by authorities. In many countries, information about urban planning is regarded as public information, often published as open data. The regulation chain considers any requirements that may be prescribed in the legal framework for conducting urban plan monitoring. The second chain accommodates functional aspects for enabling participants to monitor the implementation of the urban plan. The functional aspects aim to support participants in assessing general planning and decision situations (monitoring steps, motivation, and characteristics of an object). The third chain is describing user requirements. The participatory approach should accommodate stakeholders' preferences for spatial information needed. Local citizens should be acknowledged as internal users that can shape data governance and policy in participatory urban plan monitoring, including selecting the type and specifications of spatial information that has to be provided and shared with stakeholders.

The Indonesian regulatory framework mandated all government levels to facilitate citizens with monitoring the implementation of the urban plan. Spatial Planning Act instructs local governments to develop the GIS for spatial planning (GISTARU) for disseminating urban plans at a map scale of 1:5,000. Government regulation on spatial plan accuracy (2013) categorizes two datasets of a spatial plan: spatial structure plan and spatial pattern plan (zoning plan). The spatial structure plan consists of an urban system map and utility maps. The spatial pattern plan (or zoning map) contains zoning regulations, including Rights, Restrictions, and Responsibilities (RRRs). These regulations prescribe the GISTARU to include topography and thematic maps into its database and disseminate these types of spatial information to society. From surveys and interviews conducted in 2017 and 2019, this study found that 3D representation is widely agreed to and shared by data custodians, urban planners, and potential contributors for participatory urban plan monitoring. The result of the three-chain approach study determines nine themes of spatial information to be used for participatory urban plan monitoring in Indonesian cities, which are: public facility, building, utility networks, land cover, coastline, transportation, land-use (existing), zoning map (planned land-use) and toponym. There is a consensus that most respondents expected urban plans in 3D representation for PUPM. The selection method of spatial information for PUPM is presented in Chapter 3.

Research sub-question 2 – *What is the preferred specification of a land-use (urban) plan for participatory urban plan monitoring?*

For the past two decades, geospatial communities acknowledge the land management paradigm as the land administration horizon. This paradigm prescribes cities to provide a complete view of land management, consisting of information about land tenure, land valuation, land-use planning, and land development planning. These information types should be included in the Land Administration System (LAS) to be shared with relevant stakeholders. Since its publication, ISO 19152:2012 about the Land Administration Domain Model (LADM) has been implemented in many countries worldwide for developing their LAS. The first (current) edition of the LADM focuses on the land administration data model, emphasizing securing rights and registering property on land tenure. In comparison, cities are responsible for managing the land-use plan. In many countries, land tenure and land-use planning are managed by different authorities, and each has a specific domain. These authorities should implement the LADM data model to construct and manage a complete view of Rights, Restrictions, and Responsibilities (RRRs) and represent them in 3D space. In 2018, ISO kick-started the revision of the LADM standard and invited experts in land administration to improve it by adding more packages to construct complete RRRs information representing the actual legal situation. This dissertation presents a spatial plan information package (SP Information Package) that specifies the land-use plan proposed in the revision of LADM. This package accommodates land-use (zoning) plans in a specific class named *SP_PlanBlock*, while a set of indications of each zoning plan is stored as *SP_PlanUnit* class. The SP Information Package can improve information interoperability between land-use plan functions in the land management paradigm. Further, the proposed package can provide a more reflective the LADM country profile for Indonesian cities. These adaptive and straightforward classes reuse the *LA_BoundaryFace* class from the LADM to represent restrictions and responsibilities derived from a land-use (urban) plan in 2D and 3D formats. This study shows that SP Information Package is helpful for integrating RRRs information from land-use and land development planning with information on land tenure and land valuation in Indonesian cities. Therefore, this study advocates SP Information Package to be used in Indonesian cities to ensure information interoperability and integrity of all land management functions. Chapter 4 is focusing on the development of the SP Information Package. An example of the SP Information Package implementation with actual data (urban plans) of Jakarta and Bandung for improving the LADM country profile and supporting PUPM is illustrated in Chapters 6 and 7.

In summary, by adding the developed Spatial Plan Information Package (SP Information Package) into the next version of the LADM, both cadastre (securing rights) and spatial planning (enforcing restrictions and responsibilities) domains can share a common data model provided in the same ISO standard. This study found that SP Information Package can help urban planners standardize land-use plans to ensure information interoperability with other land management functions (i.e., land tenure, land valuation, and land development planning). Therefore, this study recommends the inclusion of the SP Information Package to revise the LADM standard to ensure a consistent and complete overview of RRRs on each land parcel or 3D space and its accompanying documents.

Research sub-question 3 *– What are the preferred criteria of open spatial data sharing to support participatory urban plan monitoring?*

Making land information accessible to broader stakeholder groups is gaining interest in many countries, particularly to improve the Ease of Doing Business. Urban plans are among land information that all stakeholders need to do business and take day-to-day decisions or high-level policy-making. Urban plans are developed and used by multiple stakeholders for various purposes, including PUPM. Amid digital transformation, spatial data custodians in land management face challenges in providing, updating, and disseminating land information for PUPM. These challenges vary from lack of budget to ever-changing urban landscape and increasing economic activities. This dissertation presents an approach to implement the PUPM in a networked system such as the SII, allowing government institutions and economic actors to exploit integrated land information for monitoring the implementation of urban plans.

Table 8-1: The Open SII strategy for supporting Participatory Urban Plan Monitoring

Criteria	Actions	Goals
1). Leadership, Open Data Governance, and Sustainable Financial and Human Resources	*1). To provide data leadership, policy, and resources to promote spatial information infrastructure as a common digital platform for spatial data sharing in cities.* *2). To construct and strengthen the foundation of the spatial data ecosystem for open participation in monitoring the implementation of the urban plan.*	**Goal 1:** Strong leadership for the development and management of Open SII for PUPM. **Goal 2:** National and local data governance are implemented for open participation. **Goal 3:** Financial and human resources are sufficient and sustainable for operationalizing Open SII for PUPM.
2). Institutional Arrangements for Open Data and Open Participation principles	*3).* To build understanding and agreement necessary for all stakeholders to perform roles to perform spatial data sharing for participatory urban plan monitoring (PUPM). *4).* To develop a mechanism for performing open spatial data and open participation to all stakeholders to perform spatial data sharing and PUPM. *5).* To continuously conduct public outreach and training to all stakeholders in continuously practicing and improving two-way information flows, data sharing, and PUPM.	**Goal 4**: Mechanism is developed and implemented for open spatial data and open participation between local government and local citizens. **Goal 5:** Partnership among local government entities and with local citizens is installed to monitor the implementation of the urban plan. **Goal 6:** Public outreach and training are organized continuously for spatial data sharing for PUPM.
3). Digital twin and Digital triplets at sufficient quality	*6). To provide 3D city models at least in LOD1 for representing the physical object and 3D RRRs from land-use planning are provided for the whole city.* *7). To implement LADM data modeling, local regulations, and other international standards (i.e., ISO and OGC)on digital twins and digital triplets to ensure interoperability.*	**Goal 7:** Digital twin and digital triplets are provided to represent the physical and legal objects of the city to all stakeholders as a standard operating map.
4). Interoperability and comparability	*7). To examine the existing Land Administration System and LADM compliancy for ensuring information interoperability of land information.* *8).To implement the Spatial Plan Information Package for data modeling of the urban plan and the international standard for 3D data exchange.*	**Goal 8:** The LADM standard is implemented for land information related to land tenure, land valuation, land-use planning, and land development planning. **Goal 9:** Digital twin and digital triplets are delivered to all stakeholders for PUPM.
5). Fit for Purpose Technology	*7).To develop tools for assisting all stakeholders in participatory urban plan monitoring*	**Goal 10:** A set of tools that enable all stakeholders to perform two-way information flows is provided to monitor the implementation of the urban plan is fully functioned.

In 2018, the UN recommended that all member countries implement Integrated Geospatial Information Framework (IGIF) to improve their spatial information management to support Sustainable Development Goals (SDGs). This study developed five criteria to establish the Open SII at the city level based on combining the contemporary SII concept and IGIF to support PUPM (Table 8-1). The Open SII concept fits the Indonesian 'One Data' Policy, and the SII supports the implementation of PUPM in Indonesian cities. Also, the Open SII has the capability to modernize its LAS by providing a collaborative platform with local governments. Further, the Open SII will improve the value of LAS by allowing participation of the broader community and promoting standardizations under the national institutional arrangements. In Indonesia's regulatory situation, such collaboration can be performed in the Indonesia SII initiative, a networked environment that facilitates spatial data sharing, including land information. However, to enable communities to access these opportunities and contribute spatial information, the current SII should be transformed into the Open SII and enable two-way information flows among all stakeholders. From surveys and interviews conducted in 2017 and 2019, both *Badan Pertanahan Nasional* (National Land Agency) and local governments plan to implement national standards, reuse crowd-sourced spatial data, and collaborate with citizens in participatory urban plan monitoring. This study proposes the introduction of open data principles into the SII to construct the Open SII. However, the Open SII model relies on the standardization of spatial information for ensuring information interoperability of information in multiple applications. Chapter 5 presents a complete overview of the development of criteria to establish Open SII, while Chapter 6 and 7 provide the implementation of the Open SII capable of facilitating a two-way information flow for PUPM.

Research sub-question 4 *– How a system that allows for spatial data sharing in participatory urban plan monitoring?*

Monitoring and evaluating the implementation of the urban plan is an integral part of urban planning. Local governments should collaborate with affected parties, the local citizens, in collecting actual signs of progress or impacts of an urban plan. Local governments use the urban plan as the reference for allocating public budgets and issuing permits for land development. At the same time, economic actors modify physical urban objects according to the urban plan. The emergence of the *digital twin* concept attempts to make 3D city models and sensors represent the city's physical objects digitally. For PUPM purposes, this study proposes the term '*digital triplets*' for representing the city's legal objects and their dynamics (i.e., transactions). Both digital twin and digital triplets are useful in participatory urban plan monitoring. All parties use them as the reference for comparing and reporting the actual condition of land (or space) utilization. This dissertation presents the Participatory Urban Plan Monitoring (PUPM) application that assists all parties in exploring, contributing, and validating 3D spatial information. The PUPM application aims to facilitate local citizens to monitor, evaluate, and report any violations, infringements, or performances of land-use (urban) plans.

The research develops the Open SII strategies to guide cities' actions in transforming their SIIs to the Open SII and support local citizens to monitor the implementation of the urban plan. The strategies contain five steps with ten goals in a specific order for cities to develop a supportive environment for participatory urban plan monitoring (see Table 8-1). In the first step, the Open SII strategy establishes data leadership capable of constructing open data governance and securing sustainable resources needed by Open SII. The second step is to develop an institutional arrangement that enables open data and open participation for all stakeholders, particularly local citizens. A two-way information flow requires open data governance that implements open data and allows open participation. All stakeholders should be informed about roles and mechanisms in exchanging spatial data in participatory urban plan monitoring. Therefore, vigorous public outreach activities and continuous training should be performed to improve stakeholders' capabilities to use spatial information to monitor urban plan implementation. The third step is to develop a *digital twin* for representing physical objects and digital triplets for legal objects and their dynamics (i.e., transactions). Both digital twin and digital triplets require a 3D representation and updating system. Participatory urban plan monitoring regards local citizens as "*sensors*" to monitor the actual condition (physical and legal) and evaluate them according to the urban plan. The fourth step is to examine the existing data models of all information in the land management function to assess information interoperability and comparability. ISO 19152:2012 about the Land Administration Domain Model (LADM) was used to develop information interoperability for land management functions (land tenure, land valuation, land-use planning, and land development planning). The last step is promoting the fit-for-purpose technology for developing tools for all stakeholders to perform a two-way information flow.

8.3 Limitations of the study

The research studied the challenge of facilitating local spatial knowledge to monitor and evaluate the implementation of the urban plan in Indonesian cities. It introduced the standardization of spatial plans and open participation to the existing spatial information infrastructure as part of the solution. After identifying spatial information and tools necessary for stakeholders in participatory urban plan monitoring, the research explored national and international data policies compared to local and national case studies as a learning mechanism to formulate strategies for Indonesian cities' context. It concluded with an online 3D web GIS application derived from the lessons identified in two case studies in Indonesian cities: Jakarta and Bandung. These strategies were discussed with relevant stakeholders in Indonesia, and the results were described in Chapters 3 to 7.

There are two main limitations regarding the final result of this study. The open data sharing strategies were developed in response to the situations identified in Indonesian cities, and therefore, the applicability of the results is limited to the Indonesian cities context. Exploration of the LADM, 3D representation, and the Open SII as the potential solutions for supporting participatory urban plan monitoring is possible in Indonesian cities for its SII elements (supporting policy, institutional frameworks, implementation of standards, and technological, financial, and human resource capabilities). Implementation of a similar approach in other countries shall depend on their elements of SII. The second limitation is about the artificial situation (not actual condition) on usability testing using 3D spatial representation for participatory urban plan monitoring. However, much research has been discussed about finding a suitable spatial representation to improve users' understanding of urban phenomena. The level of spatial thinking capability of each individual and area varies. This study still requires real situation testing to assess the exploitation of 3D representation and temporal aspects to improve the spatial thinking of stakeholders in participatory urban plan monitoring. The artificial situation testing cannot fully depict an actual implementation and guarantee its reliability. It only depicts the actual usage.

8.4 Scientific contributions

The progress in 3D information and open data sharing research play an essential role in participatory urban plan monitoring. The Open SII proposed in this research aims to provide digital representation available to stakeholders in contributing urban information as factual as possible. To ensure successful participatory urban plan monitoring, local governments in Indonesia should make land information interoperable and accessible. Current legal situations are already enabling local citizens to contribute their LSK in the form of spatial information. However, not all land information is accessible as public information, and some lack information interoperability. Further, relevant data custodians in land management do not facilitate local citizens exchanging or contributing spatial information into their system. Suppose local government disseminating relevant land information as public information. In that case, local citizens can improve the quality of spatial information contributed to participatory urban plan monitoring and decision-making for their land and property, including combining and integrating them with other information. Local government can also develop updating systems by facilitating two-way information flow, allowing local citizens to contribute their LSK onto spatial information, creating digital twin and digital triplets of a city. Thus, information interoperability should be achieved to allow information integration in land management functions (land tenure, land valuation, land-use planning, and land development plan. While detailed spatial data requirements are determined, standardization for information interoperability should also consider local regulations of cities and countries. Over the past two decades, there has been some development towards open spatial data sharing in Indonesia, the most notable of which are Spatial Information Infrastructure (SII), One Map policy, and One Data Indonesia policy. The SII at the city level was initially facilitated only for institutions within local governments. However, open data gains more popularity, and open participation creates more demands for higher information flow between land management stakeholders.

The research contributes to narrowing three knowledge gaps in participatory urban plan monitoring in Indonesian cities and worldwide. First, it explores the concept of standardization of land information, particularly for land-use (urban) plans, developing and implementing the proposed Spatial Plan Information Package of the LADM standard for the two biggest Indonesian cities: Jakarta and Bandung. Secondly, it develops a digital triplet to represent 3D RRRs for legal objects in urban areas. Thirdly, it constructs the design-research approach by integrating open data and open participation principles into the SII to create the Open SII for providing a supportive environment for the participatory urban plan monitoring. The dissertation proposes the Open SII strategy for enabling local citizens to share their local spatial knowledge via two-way information flows for participatory urban plan monitoring. Also, it explores the use of 3D spatial information in land management. The combination of standardization, open spatial data sharing, and multi-dimensional representation of objects is a novel approach to monitor the implementation of the urban plan with local citizens' involvement. The combination of the three main scientific approaches presented in this dissertation has never been explored regarding Participatory Urban Plan Monitoring (PUPM). The existing discussion of scholars mainly focused on compiling the urban plan and regarded local citizens as objects or passive subjects. The use of 3D representation for legal objects for monitoring the implementation of the urban plan is rarely discussed. Moreover, research on open data governance for enabling open participation is still in the early stages. The proposed Spatial Plan Information Package of the LADM revision contributes to materialize the land management paradigm from its land-use planning function. First, it offers the standardization of land-use (urban) plans in various formats and content to develop information interoperability while still accommodating local or national regulations. This standard package is derived from best practices from Indonesian cities and European countries to ensure information interoperability while applying to different legal situations in many countries. Second, it highlights the influence of the international standards to promote information interoperability and enable information integration among land management functions (land tenure, land valuation, land-use planning, and land development planning) and between cities or countries, for example, for monitoring urban resiliency through urban planning toward climate change or supporting sustainable development.

The second contribution is using the Open SII concept to facilitate spatial data sharing in cities, contributing to the open participation debate in cities from an innovative approach between the contemporary SII and smart city debate. First, it regards that local citizens hold local spatial knowledge as data producers. This approach brings to the relevance of two-way information flows while recognizing standards and their limitations to produce spatial information. Second, the Open SII concept focuses on the innovation in spatial data sharing, emphasizing the integration of the SII with the smart city system. Thus, the solution is closely related to facilitate spatial data sharing and enable local citizens to contribute their local spatial knowledge in the form of spatial information into the urban plan monitoring system. The third contribution is the development of digital triplets and the combination of digital twin and digital triplets for participatory urban plan monitoring to improve the spatial thinking of all stakeholders in monitoring the implementation of the urban plan. While a digital twin represents physical objects, the digital triplets depict the legal situation and its Rights, Restrictions, and Responsibilities (RRRs) in 3D representation. Both digital twin and digital triplets are needed and function as a reference for participatory urban plan monitoring and other applications in cities and municipalities. This research also provides two 3D Web-based GIS applications as proofs of concept and helps readers understand digital triplets[7] and two-way information flows on an Open SII[8].

8.5 Societal contributions

This research proposes standardization that may play a key role in improving information interoperability of land-use (urban) plans. The Spatial Plan Information Package has been implemented with the real urban plan of two case studies in Indonesian cities: Jakarta and Bandung. Local citizens in these cities are experiencing changes in their livelihood, leading to new opportunities or threats. The inclusion of access to land information, precisely on a 3D urban plan or digital triplets (3D RRRs), may improve local citizens' capability to monitor the implementation of the urban plan. This dissertation presented the development of the Open SII from existing SII for Indonesian cities, considering local citizens beyond their role as an object or passive subject in urban plan monitoring, exploring a novel innovation to access, analyze, and share 3D spatial information in the field of land management. The proposed standardization of land-use (urban) plan and the Open SII strategy illustrate the opportunity to improve the current practice of urban plan monitoring by promoting local government-local citizen collaboration and opening new

[7] http://pakhuis.tudelft.nl:8080/edu/cesium74/Apps/pupm2/
[8] https://tanahair.indonesia.go.id/pupm

areas of reusing 3D visualization to represent RRRs. Although the standardization and the Open SII strategy are focused on spatial information, this research aims to improve the quality of information contributed by local citizens for monitoring urban plan monitoring.

8.6 Recommendations for further development

Spatial information plays a critical role in monitoring and evaluating urban plan implementation, particularly its specification, representation, interoperability, and accessibility. Further, as the affected party, local citizens should monitor and evaluate the urban plan's implementation. Local citizens should be able to access, use and contribute spatial information to report actual phenomena and evaluate their characteristics with the urban plan. This dissertation presents theoretical and practical aspects to develop a feasible framework for actors in cities to establish a supportive environment for Participatory Urban Plan Monitoring (PUPM). To answer this, as the leading actors in participatory urban plan monitoring, local governments in Indonesia should implement the strategy formulated in Section 8.2.

This study highlights the implementation of the SP Information Package in cities to support local governments in managing their urban plans towards sustainable development. The proposed SP Information Package integrates information from land-use planning and land development planning with land tenure and land valuation in the LADM standard. Therefore, this research advocates that the SP Information Package to be part of the revised version of ISO 19152 to provide a complete view of legal situations of land parcels and urban space. This research recommends further investigation for implementation of the SP Information Package of the LADM to improve the capability of LAS to manage information from land management functions (land tenure, land valuation, land-use planning, and land development planning).

LAS requires reliable spatial data sharing as many cities delegate their land management functions to different organizations. LAS contains spatial information which economic actors need to organize and manage their land, space, and property. Therefore, Land Administration System (LAS) scope should be expanded not only for land tenure or cadastre only, but also to cover land valuation, land-use planning, and land development planning. Also, LAS should facilitate broader stakeholders, including landowners and investors, to access and contribute spatial information. This dissertation presents the integration of open data and open participation principles with Spatial Information Infrastructure (SII) to construct Open SII. Since the SII and smart city share common elements, this research proposes more studies focusing on integrating these initiatives, particularly open spatial information sharing.

Many cities are developing their digital twin by exploiting 3D city models to represent urban's physical objects and updating systems. The use of 3D spatial information is not only for improving spatial thinking but also for representing the actual object. This dissertation proposes digital triplets to represent Rights, Restrictions, and Responsibilities (RRRs) in Participatory Urban Plan Monitoring (PUPM). This study found that digital twin and digital triplet are required in PUPM. Local citizens should be allowed to contribute their LSK in the form of spatial information and function as updating system. Therefore, this study recommends more study on establishing the Open SII to facilitate local citizens to contribute spatial information containing their Local Spatial Knowledge (LSK), including in 3D spatial representation. The Open SII facilitates stakeholders to access relevant spatial data and tools for participatory urban plan monitoring. The Open SII can organize all stakeholders to perform specific roles to enable two-way information flows for monitoring the implementation of the urban plan. The Open SII considers all stakeholders as contributors (data producers) and fosters local citizens' capability to use Geo-ICT and collaboration authorities and local governments.

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A. Annex
Requirements from Regulations and Questionnaire

Table A-1 List of spatial information required urban planning process
This list contains maps at scale 1:5000 or better produced by government institutions (Ministry of Public Works Regulation, 2011).

Type of spatial data	Description
Coastline	A line of land-to-sea encounters that are affected by tides. The coastline consists of: the lowest receding coastline; highest tidal coastline; and coastline average sea level.
Hypsography	A height data that can be described in various ways, such as high points, digital elevation models, lines connecting dots of the same height (contour lines), or colors that reflect altitude.
Water bodies	The area that indicates the surface of the water body (water mass) in a particular region, such as the sea, rivers, lakes, and swamps.
Toponym	The name was given to topographic elements, whether in the form of natural or artificial elements.
Administration boundaries	An imaginary line that describes the limits of the inter-village and village, inter-district, inter-regency/city, interprovincial, and interstate.
Transportation and utilities	Physical infrastructure for the movement of people and goods from one place to another.
Buildings and public facilities	Contains the artificial objects and various kinds of public facilities that intangible buildings.
Land cover	Describes the cover above the earth's surface consisting of landscape and an artificial landscape.
Physiographic	Describes physical patterns and processes of the Earth or a description of the features and phenomena of nature.
Demographic	Population size and structure, including fertility, mortality and international migration.
Economy and Financial	Describes the location and zone of economic and financial activity, including public services, such as markets, shopping centers, banks, ATM, and others.
Land-use	The functional dimension of land for different purposes or economic activities.
Rainfall	The amount of water that falls on the ground surface flat for a period measured by unit height (mm) above the horizontal surface in the absence of evaporation, runoff, and infiltration.
Slope/Morphometry	"A slope is the rise or fall of the land surface" [6]; a rising or falling surface. This data describes the process of measuring the external shape and dimensions of landforms, living organisms, or other objects

Table A-1 (continued). List of spatial information required urban planning process at map scale 1:5000 or better (Ministry of Public Works Regulation, 2011) produced by government institutions.

Type of spatial data	Description
Morphology	The physical features of the earth and their relation to its geological structures.
Soil	A geographical representation showing the diversity of soil types and soil properties (e.g., soil pH, textures, organic matter, depths of horizons).
Geology	Depicts the distribution of different kinds of rock, surficial deposits, and locations of geologic structures, such as faults and folds.
Land tenure	Represents the relationship, whether legally or customarily defined, among people, as individuals or groups, concerning land.
Hazard	Highlights areas that are affected by a hazard or an unsafe to a particular hazard. The hazard map typically contains information related to natural hazards, such as earthquakes, volcanoes, landslides, flooding, and tsunamis. Hazard maps help prevent severe damage and deaths.
Critical Area	Describes land or land that is currently unproductive due to the management and use of land that is not or is less concerned with soil and water conservation requirements, so that the land is damaged, lost, or reduced function to the already established or expected limits.
Land suitability	The level of suitability of a plot of land for a particular use. The classification of land suitability is the matching between the land quality and the desired land-use requirements.

Table A-2 List of urban zonation maps produced in the urban planning processes
This list contains layers at map scale 1:5000 or better (Ministry of Public Works Regulation, 2011) produced by the city government.

Type	Description
	Profile Planning
Orientation Map	The geographical position of a planning area.
Administration Boundary	A delineation or demarcation lines of a planning area.
Land-use	A delineation of existing land-use types (in reality) throughout the planning area.
Disaster Risk	A delineation of disaster-prone areas classified by level the danger.
Population Distribution	Distribution of population density of each planning area to illustrate where population concentrations exist.
	Urban Infrastructure Plan
Transportation Development plan	A network of mobility plan describes the entire primary network and secondary network in the planning area which includes arterial road, collector road, local road, environmental road, and another road network.
Energy infrastructure Development plan	An energy and power plan map that describes all sub-transmission networks, primary distribution networks (High Voltage Cable, Extra High Voltage Cable, and Ultra High Voltage Cable), secondary distribution networks, oil and gas pipelines, and all other supporting buildings included in those networks.
Telecommunication and Information Infrastructure Development Plan	A map of telecommunication network development plan containing basic telecommunication infrastructure development plan. This map contains the central location of telecommunication connection and cable network of cable (primary and secondary cable networks).
Drinking (Clean) Water Development Plan	A map containing water-supply network development plan includes the drinking water supply system of the planning area, pipeline network system instead of the pipeline network, raw water pickup building, raw water transmission pipes and production installations, distribution pipelines, and related buildings.
Drainage Development Plan	A map of the drainage network development plan contains a primary, secondary, tertiary, and neighborhood drainage plan.
Waste/Sewage Development Plan	A map containing Wastewater Sewage Development Plan includes on-site and off-site disposal systems in the planning area along with all wastewater treatment buildings.
Specific Development Plan	A map containing another type of infrastructure which is needed in the planning area, e.g., the disaster evacuation route plan.

Table A-2 (continued). List of zonation maps produced in the urban planning processes This list contains layers at map scale 1:5000 or better (Ministry of Public Works Regulation, 2011) produced by the city government.

Type	Description
Urban Zonation	
Conservation	A map containing zonation to preserve ecosystem includes: 1. protected forest zones; 2. protection against the underlying zones, including peat zones and water catchment zones; 3. local protection zones, including coastal borders, river borders, zones around lakes or reservoirs, zones around springs; 4. urban green opening zones, including parks, city parks, and cemeteries; 5. nature reserve and cultural preservation zones; 6. disaster-risk zones, including landslide prone zones, tidal prone zones, and flood-prone zones; and 7. other protected zones.
Cultivation	A map containing zonation to support cultivation activities includes: 1. residential zones, 2. trade and services zones, 3. office space zones, 4. public service facility zones, 5. industrial zones, 6. special zones, including defense and security purposes zone, Wastewater Treatment Wastewater zones, Waste Processing zones, and other special zones; 7. other zones include agricultural zones, mining zones, and tourism zones; and 8. mixed zone, which contains several functional and integrated functions (housing and trade/services, housing, etc.)
Specific	A map containing zonation for to support specific activities includes: 1. flight operation safety zone; 2. cultural or customary preservation zones; 3. disaster risk zones; 4. defense and security zone; 5. research zone; 6. nuclear development zone; 7. power plants zones; 8. electric substation zone; 9. clean water sources zone; and 10. wireless telecommunication zones.
Priority Area	
Priority Area	A map contains delineation of prioritized zone in planning area.

Table A-3 Questionnaire

Name of institution	:	....	Government:	☐Yes ☐No
Responsibility	:	....		
Management level	:	☐Upper	☐Middle	☐Lower
		Develop objectives, strategic plans, policies direction, and organizational decision-making	Implement organizational plan compliances with policies and organizational objectives	Guiding and supervising employees in everyday activities

1. Do you or your institution have special and sustainable programs to produce, maintain, and update specific spatial information?

☐ Yes	☐ No

2. Do you or your institution need spatial information layer on detailed map scale (1: 5,000 or better) below?
   Which information layers do you or your institution need to be accessed via the Spatial Information Infrastructure?

Themes	Needed?	Utilized?
Digital Elevation Models/ DEM (include Contour lines)		
Satellite Ortho-Imageries or Aerial Ortho-Photo		
Toponym (place name) and Point of Interest		
Coastline		
Building		
Public facilities		
Transportation (include Roads, Runways, Ports, etc.)		
Utilities (including, cables, pipes, hydrants, etc.)		
Land cover (including, vegetation, etc.)		
Land-use		
Urban Zonation (include Permissions, restrictions, etc.)		
Land rights (tenure)		
Land value		
Soil		
Geology		

3. What is your expectation of geometric accuracy for decision making in urban planning?

☐ coarse (10 meters)	☐ secondary (5 meters)	☐ details (1 m)	☐ very detailed (Sub 1 m)

4. What is your expectation of geometric quality for law enforcement, engineering works, and land matters (example: to measure the length and calculate the area) in urban planning?

☐ coarse (10 meters)	☐ medium (5 meters)	☐ Sophisticated (1 m)	☐ very detailed (sub 1 m)

5. Do you think 3D spatial information will improve your spatial cognitive ability in the urban planning implementation monitoring and evaluation?

☐ Yes	☐ No	☐ Maybe

If your answer is "**YES**," which layers are needed?

Themes	**Needed?**	**Utilized?**
Digital Elevation Models/ DEM (include Contour lines)	☐	☐
Satellite Ortho-Imageries or Aerial Ortho-Photo	☐	☐
Toponym (place name) and Point of Interest	☐	☐
Coastline	☐	☐
Building	☐	☐
Public facilities	☐	☐
Transportation (include Roads, Runways, Ports, etc.)	☐	☐
Utilities (including, cables, pipes, hydrants, etc.)	☐	☐
Land cover (including, vegetation, etc.)	☐	☐
Land-use	☐	☐
Urban Zonation (include Permissions, restrictions, etc.)	☐	☐
Land rights (tenure)	☐	☐
Land value	☐	☐
Soil	☐	☐
Geology	☐	☐

6. What kind of tools do you choose to perform participatory the of urban planning monitoring and evaluation?

☐ software on the PC	☐ web applications	☐ mobile app

7. Do you need maps or any relevant spatial information installed in participatory the implementation of urban planning monitoring and evaluation tools?

☐ Yes	☐ No	☐ Maybe

B. Annex Data Dictionary for Urban Plan in Indonesia

Table B-1. Information in Attribute Table Field for urban plan

Name	Code	Explanatory
Object name	NAMOBJ	classification of derivatives of the last order elements in the regional spatial plan according to the plan scale. Contains local elements and/or derived elements in the province/regency/city
Types of Structure Plans	JNSRSR	types of spatial structure plans that include the arrangement of service centers and infrastructure networks in the Planning Area Section
Feature name 1	ORDE01	classification of derived elements of the order-1 type of spatial structure plan
Feature name 2	ORDE02	classification of derived elements of the order-2 type of spatial structure plan
Zone name	NAMZON	the zone classification in the spatial pattern plan
Zone code	KODZON	the zoning code used in the spatial pattern plan
Subzone name	KODSZN	the classification of zone derivatives in the spatial pattern plan
Block code	KODBLK	the code for a plot of land that is limited by at least a real physical boundary.
SubBlock code	KODSBL	the block code derivative for a plot of land delimited by at least a real physical boundary.
Administrative Region	WADMKC	the administrative area unit of urban plan where the object is located
Planning Area Section	NAMBWP	the regional units that are part of the Municipality/city and /or strategic areas for which urban plan will be or need to be compiled, following the directions or stipulated in the Municipality/City's spatial plan.
Sub Division of Planning Area	NASBWP	part of the BWP that is delimited with physical boundaries and consists of several blocks.
Special provisions		the additional rules that are stacked (overlay) over a particular zone/subzone because there are special things that require its structure, which consists of::
	KKOP_1	Airport, including the Safety Area of Aviation Operations (KKOP), the Noise Area, and the Area around the airport which are essential to be noticed
	LP2B_2	Land Agriculture Sustainable Food (LP2B)
	KRB_03	Disaster-prone areas
	TOD_04	Transit-Oriented Area (TOD)
	TEB_05	Disaster Evacuation Sites including temporary evacuation sites and final evacuation sites
	CAGBUD	Cultural or Customary Reserves
	HANKAM	Defense Security (Defense)
	PUSLIT	Research Center includes observatories, rocket launching sites, and others
Zoning Arrangement Techniques	TPZ_00	the rules for overcoming the rigidity of the baseline in the implementation of development, the number of columns depends on the number of TZ related to the number of points.
Network Status	STSJRN	the network status consists of the new network plan or the development of the existing or existing conditions and can be filled in with the description "plan" or "existing."
Data source	SBDATA	the source of the data originating and the documents issued
Zone Area	LUASHA	the extent of the supervisory area in hectares (Ha)

Table B-2 Type of Zoning criteria for urban plan map for Municipality/City

Name	ID	Explanatory
Transfer Development Right (TDR)	a	A zoning arrangement technique allows landowners to sell their rights to build to other parties so that buyers can build their properties with greater intensity. The TDR requires a plan indicating which zones to conserve or protect from development (sending areas) or to develop or encourage development (receiving areas).
Zoning Bonus	b	A zoning regulation technique grants a developer permission to add space utilization intensity beyond the basic rules. In exchange for (compensation), the developer must provide specific public facilities (i.e., green open space, crossing tunnels).
Conditional Uses	c	A zoning arrangement technique allows a space utilization deemed necessary to be included in a specific designation zone even though its characteristics do not meet the zoning criteria. A Conditional Use Permits (CUP) can be introduced after public consultations or discussions with local communities and considerations of related agencies in the region.
Performance Zone	d	A zoning arrangement technique is an arrangement provision in one or several zones/subzones in a block or several blocks whose rules are not based on perspective rules but are based on certain specified performance qualities. Performance zones are designed to set measurable standards for physical conditions and be followed by binding performance standards.
Fiscal Zone	e	A zoning arrangement technique determines in one zone or several zones that are oriented towards increasing regional income.
Development Agreement	f	A zoning regulation technique is a regulatory provision on zones that specifically allow development to be carried out based on an agreement between stakeholders.
Overlay	g	A zoning regulation technique allows flexibility in applying zoning regulations to limit development intensity through the application of two or more rules. It can be applied as a form of disincentive to provide certain conditions in licensing.
Threshold Zone	h	The zoning regulation technique, which is the regulatory provisions on the allocation block. It is symbolized by land- or space-use and space designation and determined later based on space utilization development in the allocated block.
Flood Zone	i	A zoning regulation techniques are regulatory provisions for flood-prone zones to prevent or reduce losses due to flooding. The application of a flood zone meets the criteria for the location that has been identified as prone to flood disasters based on an analysis of annual flooding to a certain annual period and based on vulnerability and risk analysis of floods.
Special TPZ	j	A zoning regulation technique provides development restrictions to maintain the characteristics and/or particular objects belonging to the zoning regulations zone. It can be applied as a form of disincentive to provide certain conditions in licensing.

Table B-2 (continued). Type of Zoning criteria for urban plan map for Municipality/City

Name	ID	Explanatory
Growth Control	k	A zoning regulation technique is regulatory provisions on a zone to control or limit development in a zone, area, or corridor to maintain or protect its characteristics.
Preservation of Cultural Heritage	l	A zoning regulation technique is a regulatory provision on zones to maintain visual and cultural characters, buildings, and local community areas as stipulated in statutory regulations. The provisions for the conservation zone of the cultural heritage area can become the intersection zone if there are already provisions related to the cultural heritage area's provisions. Preservation of cultural heritage areas at least fulfills the criteria for having buildings and sites with specific cultural values.

Table B-3. Type of zoning regulation (Ministry of Spatial Planning 2020)

Code	Zoning
HL-0	Protected forest
RTH-1	City forest
RTH-2	City park
RTH-3	District park
RTH-4	Village park
RTH-5	Sub village park
RTH-6	Neighborhood park
RTH-7	Cemetery
R-1	Very High Density
R-2	High Density
R-3	Medium Density
R-4	Low Density
R-5	Very Low Density
R-m	Luxury Homes
R-h	Middle House
R-a	Very Simple House
K-1	City Scale Trade and Service
K-2	Planning Area Boundary Trade and Service
K-3	Sub Planning Area Boundary Trade and Service
KT-1	Government Offices
KT-2	Private Offices
KT-3	Foreign Offices
SPU-1	City-wide
SPU-1.1	City-Education
SPU-1.2	City-Transportation
SPU-1.3	City-Health
SPU-1.4	City-Sport
SPU-1.5	City-Religious
SPU-1.6	City-Socio-Cultural
KI	Industrial Estate

Code	Zoning
PL-1	Mining
PL-2	Open Non-Green
PL-3	Temporary Evacuation Shelter
PL-4	Permanent Evacuation Shelter
PL-5	Informal Sector
PL-6	Wastewater Treatment Plant (IPAL)
PL-7	Nuclear Development
PL-8	Power Plant
PL-9	Warehousing
C-0	Mixed Zone

Table B-4. Sample type of zoning regulation (Ministry of Spatial Planning 2020)

Code	Zoning	Height
HL-0	Protected forest	0
RTH-1	City forest	0
RTH-2	City park	0
RTH-3	District park	0
RTH-4	Village park	0
RTH-5	Sub village park	0
RTH-6	Neighborhood park	0
RTH-7	Cemetery	0
R-1	Very High Density	50
R-2	High Density	30
R-3	Medium Density	30
R-4	Low Density	30
R-5	Very Low Density	20
R-m	Luxury Homes	30
R-h	Middle House	30
R-a	Very Simple House	15
K-1	City Scale Trade and Service	50
K-2	Planning Area Boundary Trade and Service	40
K-3	Sub Planning Area Boundary Trade and Service	40
KT-1	Government Offices	40
KT-2	Private Offices	50
KT-3	Foreign Offices	40
SPU-1	City-wide	25
SPU-1.1	City-Education	25
SPU-1.2	City-Transportation	25
SPU-1.3	City-Health	25
SPU-1.4	City-Sport	25
SPU-1.5	City-Religious	25
SPU-1.6	City-Socio-Cultural	25
KI	Industrial Estate	40
PL-1	Mining	30
PL-2	Open Non-Green	0
PL-3	Temporary Evacuation Shelter	40
PL-4	Permanent Evacuation Shelter	20

C. Annex
Information Architecture for the Open SII

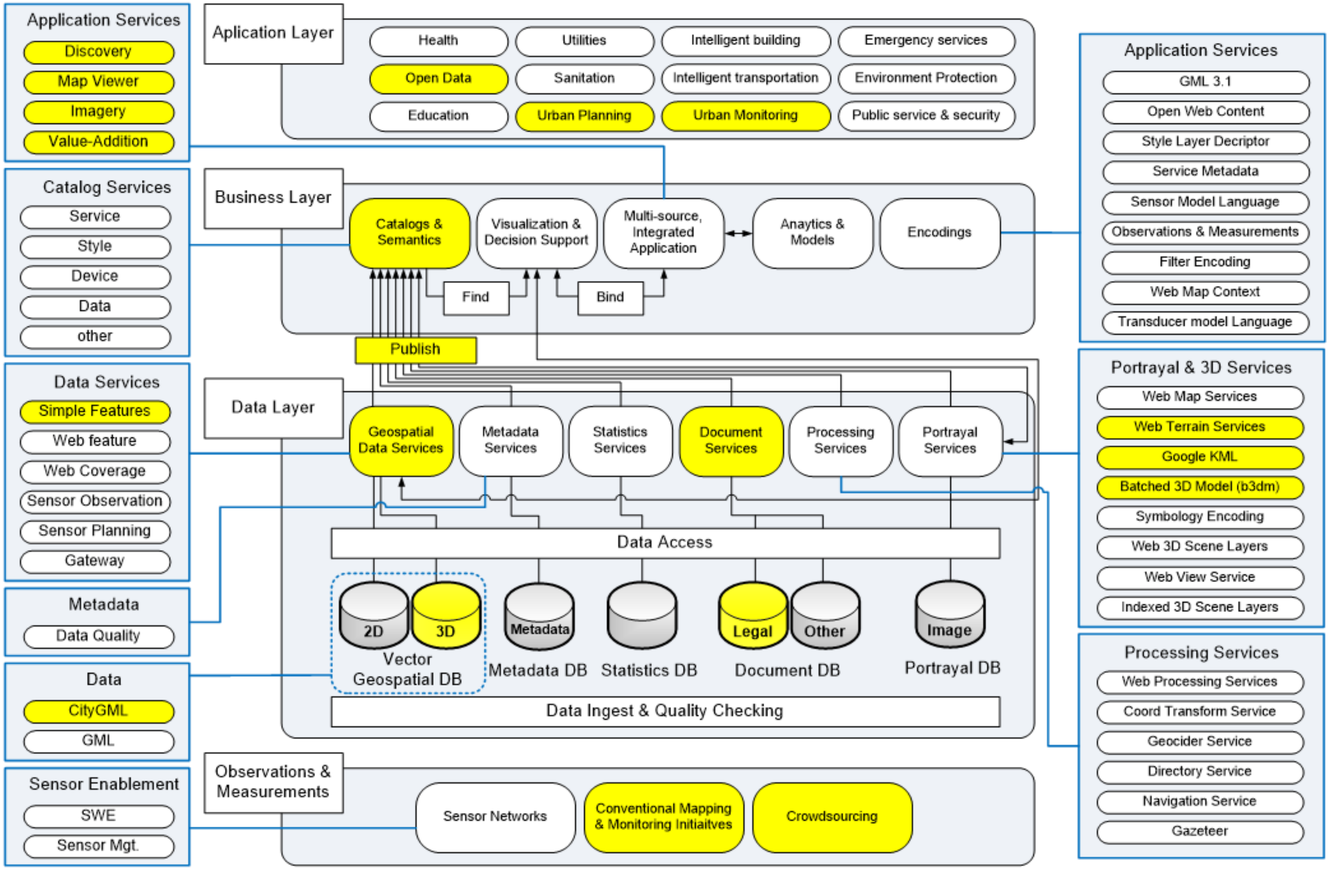


Figure C-1 OGC Web Services Framework on Enterprise Component of Smart Cities (Percivall et al. 2011 & 2015).

D. Annex
Type of Rights, Restrictions, and Responsibilities in Indonesia

Table D-1: Type of Rights on Land Parcel/Space in Indonesia

No.	Type	Definition
1	Ownership Rights (Eigendomrechts) *	Rights of ownership are hereditary rights and are the strongest, and the fullest right one can have on land that may be possessed by an Indonesian citizen. This right may go over to and transferred to another party.
2	Exploitation Rights (Erpachtrechts) *	Rights to cultivate the land which is directly controlled by the State for a period of time. This right is typical in farming, plantations, fishing, or cattle-raising, which may go over and be transferred to another party. The validity of the exploitation rights is for periods of 25 or 35 years and can be further extended for another 25 years based on the formal assessment.
3	Building Rights *	Rights to construct and to own buildings on the land, which is not one's property for a period of no longer than 30 years.
4	Rights of Use *	Rights to use and collect the product from land is directly controlled by the State or land owned by other persons who give the privileges and obligations designated in the decision upon granting this right by the authority, or in the agreement to work the land,
5	Rights to lease *	Rights to lease land with lawful payment.
6	Rights of opening-up land of collecting forest product *	Rights opening-up land and of collecting forest products by Indonesian Citizens or Government Regulation.
7	Rights of using water, for breeding and catching fish.	Rights to obtain water for a specific purpose and to flow it over another person's land.
8	Rights of using air space *	Rights of using air space authorize the utilization of energy and elements in the air space to maintain the developing the fertility of the earth, water, and natural resources contained therein and other matters relating to it

9	Rights on land for religious and social purposes *	Rights of ownership on the land of religious and social institutions for social and religious purposes.
10	Pawn Rights	Rights of control and exploit land belonging to another person, who has received a mortgage until the mortgage is returned.

Table D-1 (continued): Type of Rights on Land Parcel/Space in Indonesia

No.	Type	Definition
11	Rights of Profit-Sharing *	Rights to profit-sharing on land owned by another person based on an agreement between parties.
12	Rights of lodging (Opstalrechts) *	A type of right to authorize a person to establish or occupy a building or land owned by another person based on trust or an unwritten agreement.
13	Strata title **	The ownership rights of an apartment unit include joint ownership of public space in a building complex. The strata title concept separates rights from several strata or levels, namely the rights to the land surface, the earth below the ground, and the air above it.
14	Easement Rights ***	Rights are benefiting property or a piece of land that is enjoyed over another piece of land owned by somebody else.
15	Rights of way ***	Rights to pass along the way over property owned by another party.
16	Rights to propose ***	Rights to propose consideration on determining the direction of development;
17	Rights to clarify ***	Rights to identify the potentials and impacts from development, including rights to clarify access and benefiting from land, space, and spatial planning
18	Rights to object ***	Rights to spatial object plan and the implementation of the spatial plan

Table D-2: Type of Restrictions on Land Parcel/Space in Indonesia

No.	Type	Definition
1	Building Boundary Line (*GarisSempadanBangunan*/GSB) ***	A line that limits the minimum clearances from the outermost side of a building mass to the boundary of the controlled land. The building boundary line is functioned as a space divider, or the minimum clearances from the outermost plane of a building mass to the land parcel, river or beach boundary, between the mass of another building or channel plan, high voltage electricity network, gas pipeline network, and so forth.
2	Building Floor Coefficient (*KoefisienLantaiBangunan*/KLB) ***	The basic ratio criteria between the total floor area of the building and the area of land parcel allowed to be built.
3	Building Base Coefficient (*KoefisienDasarBangunan*/ KDB) ***	The percentage ratio between the total area of the ground floor of a building and the area of land parcel allowed to be built
4	Green Base Coefficient (*KoefisienDasarHijau* / KDH) ***	The percentage ratio between the total area of open space outside the building intended for landscaping /greening and a land parcel by the spatial plan and building and neighborhood plans.
5	Basement Site Coefficient (*KoefisienTapakBasement*/ KTB) ***	The ratio (percentage) between the basement and land plot/planning area (regulated by the spatial plan and building and neighborhood plans).
6	Built-up Area Coefficient (*Koefisien Wilayah Terbangun*/KWT) ***	The ratio (percentage) between the area of built-up blocks (allotment) with the total unconstructed allotment within the planned area.
7	Building Density (*KepadatanBangunan*) ***	The percentage ratio between the area of built-up blocks (allotment) with the total planned area.
8	Zoning regulations ***	The provisions governing the use of space and control mechanisms for each zone by the detailed spatial plan.

Table D-3: Type of Responsibilities on Land Parcel/Space in Indonesia

No.	Type	Definition
1	Protect the environment and ecosystem ****	To maintain the preservation of environmental functions and to prevent and overcome pollution and destruction.
2	Provide information about environmental management ****	To provide correct and accurate information regarding environmental management performed in specific land owned or controlled.
3	To utilize land parcel within schedule prescribed in the zoning regulation ***	To utilize or perform an activity on a land parcel or space according to zoning regulation
4	Compliance with permitting ***	To utilize or perform an activity on a land parcel or space according to permit.
5	Maintain and improve the quality of land or space ****	To perform a necessary activity in maintaining or improving the quality of land or space owned or controlled and public space.

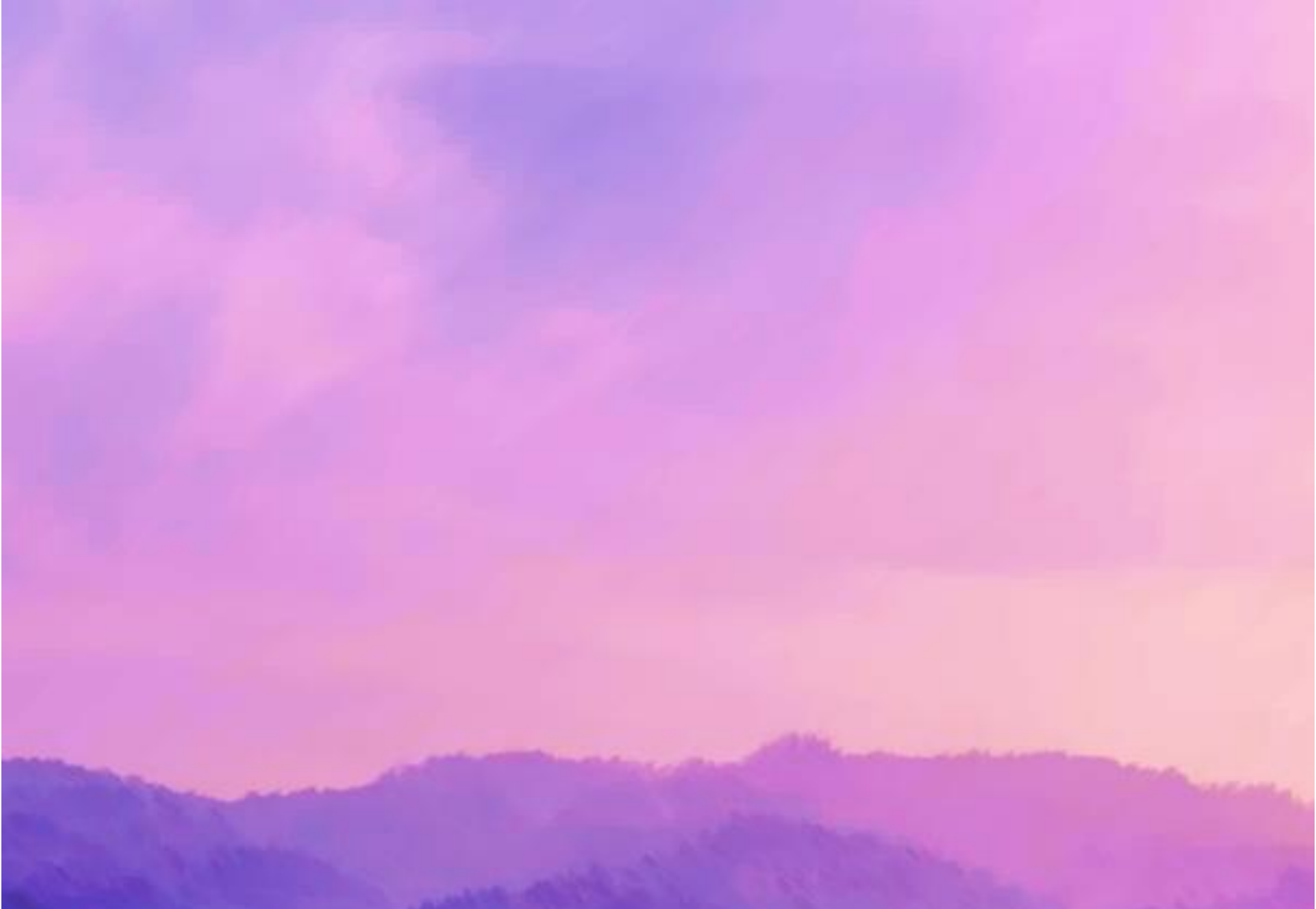
*) Basic Agrarian Principle Law (1960); **) Apartment Law (1985); ***) Spatial Planning Law (2006); and
****) Environmental Management Law (1997)

About the Author

Agung Indrajit was born in Jakarta, Indonesia, on August 28, 1974. He took a major in Geodesy engineering at the Institute of Technology of Bandung, Indonesia. He has been working as a geoinformatics engineer at the Indonesian Geospatial Information Agency (BIG) since 2002 and Chaired as Head of Spatial Data Management from 2012-2016. While working for BIG, he was responsible for establishing the Indonesian Tsunami Early Warning System (2005-2008) and Indonesia Spatial Data Infrastructure (2008-2011). He is co-author of National Geographical Feature Catalogue, Presidential Decree on data governance on high-resolution satellite imagery (2010), and Presidential Decree on National Spatial Data Infrastructure (2014)

From 2006 to 2008, He studied at Technische Universität München. There, he obtained his Master of Science degree in Earth Oriented Space Science and Technology. His M.Sc thesis entitled "*Development and Application of Remote Sensing Techniques to Support The Mapping of Settlement Areas as Contribution to Tsunami Vulnerability Assessment in Indonesia, Case Study: Cilacap And Padang."* was supported by the German Aerospace Center (DLR) and DAAD within the German-Indonesian Tsunami Early Warning System project.

Agung conducted his Ph.D. research on "*4D Open Spatial Information Infrastructure-Participatory Urban Plan Monitoring In Indonesian Cities"*, funded by the Research & Innovation In Science & Technology Project of Ministry of Research and Technology, Republic of Indonesia. He is supervised by Prof. ir Peter van Oosterom and dr. ir. Bastiaan van Loenen at Faculty of Architecture and the Built Environment, Technical University of Delft. During his time at TU Delft, he helped to teach Sensing Technology and supervised three Master Theses. He is actively as contributor at the Knowledge Center Open Data, TU Delft on Spatial Data Infrastructures. He is also a member of International Federation of Surveyor (FIG) and TU Delft team for improving ISO 19152 on the LADM. During his Ph.D. research, Agung received the best paper award at the 6th International FIG Workshop on 3D Cadastres and the 3rd International Conference on Smart Data and Smart Cities for the paper titled: *"Designing Open Spatial Information Infrastructure to Support 3D Urban Planning in Jakarta Smart City*".



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