DELIBERATIVE DIGITAL TWINS FOR REFORMING PARTICIPATORY PLANNING IN INDONESIA: A SMART GOVERNANCE FRAMEWORK

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Abstract

The Development Planning Deliberation (*Musrenbang*) is a pillar of participatory democracy in Indonesia that has systematically failed to fulfill its deliberative mandate. The objective of this study is to propose and critically examine a "Deliberative Digital Twin" as a second-wave socio-technical intervention. Unlike previous digitalization efforts (*e*-Musrenbang) that merely digitized existing bureaucratic flows, this model integrates Urban Digital Twin (UDT) with System Dynamics (SD) and Agent-Based Modeling (ABM) to create a transparent policy evaluation ecosystem. Specifically, this framework aims to disrupt the political deadlock between the technocratic planning body (*Bappeda*) and the political interest of the legislature (*DPRD*) by arming non-expert citizens with evidence-based policy impact simulations. We present a multi-layered conceptual architecture for this model and provide a critical anticipatory analysis of implementation barriers, including institutional inertia and national data infrastructure challenges. We conclude that while high-risk, the Deliberative Digital Twin offers a new paradigm for shifting *Musrenbang* from a ritualistic procedure to an authentic, evidence-based participatory governance mechanism.

Keywords: *deliberative planning, digital twin, musrenbang, public participatory, smart governance*

Introduction

Indonesia's transition to democracy since 1998 has been marked by ambitious institutional reforms aimed at decentralizing power and deepening citizen engagement. At the heart of Indonesia's post-reform decentralization architecture, the Development Planning Deliberation (Musrenbang) stands as the promise of participatory democracy. Its name alone—a portmanteau of musyawarah (deliberation), perencanaan (planning), and pembangunan (development)—refers to a deeply rooted cultural tradition of consensus-building to legitimize this process as an antithesis to the centralized, top-down development of the New Order era.

Institutionalized through Law No. 25/2004 concerning the National Development Planning System, Musrenbang is theoretically designed as a bottom-up channel for citizens to influence the allocation of public resources. This process operates hierarchically, starting from the hamlet/neighborhood (dusun/RW) level, moving up to the village/sub-district (desa/ kelurahan), district (kecamatan), regency/city (kabupaten/ kota), province, and finally national level. Ideally, it is a mechanism where the most pressing grassroots aspirations are filtered and prioritized to form the basis for preparing the Regional Government Work Plan (RKPD) and the Regional Budget (APBD). In theory, Musrenbang is a vital channel for citizens to influence public resource allocation outside of elections, as well as to encourage transparency,

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accountability, and a sense of community ownership over development projects.

However, more than two decades of its implementation have revealed a "participatory paradox" (Parvin, 2021): a mechanism designed for empowerment has often become an instrument that legitimizes exclusion and perpetuates the status quo. This dysfunction is rooted in the phenomenon of "elite capture," where local political and economic actors with better information and connections control the agenda to serve their interests (Olken, 2007; Platteau, 2004). Ordinary citizens, especially from poor and marginalized groups, enter the deliberation space in a weak position. They lack access to budget data, spatial maps, or comprehensive needs analysis. Instead, they face bureaucrats who master technical jargon and politicians who bring shopping lists from their constituents or sponsors. Consequently, the process degrades into ceremonialism or "ceremonial budgeting" (Sopanah, 2012), where participation becomes a ritual without substance to fulfill legal requirements, while real decisions are made in opaque negotiations between the executive and legislative branches.

This failure is exacerbated by Indonesia's symmetric decentralization approach, which applies a uniform governance model to regions with vastly different fiscal capacities, bureaucracies, and community readiness. This often creates ripe conditions for elite domination, especially in areas with weak civil society and high dependence on political patronage (Dlugosch, Westmore, Glanville, Hooley, & Ozturk, 2025; Hadiz, 2010). The proposals that pass are often not those most urgent for the public, but those that are most politically profitable, such as the construction of conspicuous monumental infrastructure rather than long-term investments in sanitation or education quality.

In response to these inefficiencies and criticisms, many local governments adopted the first-wave digital solution, e-Musrenbang. However, this platform proved to be a classic example of techno-solutionism—the mistaken belief that technological solutions can fix problems that are fundamentally political and structural (Morozov, 2013). Despite improving procedural transparency in proposal submissions, e-Musrenbang failed to change the underlying power dynamics. It merely digitized a flawed process without resolving it (Anindito, Sagala, & Tarigan, 2022). The platform became a more efficient digital cover for a book whose internal structure remained the same. This failure aligns with the broader implementation challenges of e-government in developing countries, which are often hampered by data silos, resistant bureaucratic cultures, and a gap between system design and the realities of the local context (Hafel, Jamil, Umasugi, & Anfas, 2022; Heeks, 2003).

This failure demands a radical, second-wave intervention that touches not only the procedure but the core of the deliberation itself. This article proposes and analyzes a conceptual model we call the "Deliberative Digital Twin." Unlike previous approaches, this model is explicitly designed as a socio-technical intervention. This intervention aims to disrupt the information asymmetry of publicly accessible policies. Its goal is to transform Musrenbang from an arena of competing interests into an arena of competing evidence, in line with the ideals of deliberative democracy (Dyrzek, 2002; Habermas, 2015). This article will detail the model's technical architecture, critically analyze its implementation challenges within the Indonesian political landscape, and propose a robust evaluation framework.

The proposed model is based on a synthesis of several theoretical frameworks to deeply diagnose the problem and formulate a solution rooted in a strong conceptual understanding. The proposed model is built upon a synthesis of several existing and innovative theoretical frameworks. This approach allows for a comprehensive and in-depth diagnosis of the problem, identifying not only the symptoms but also the underlying root causes. Thus, the solution formulated is not just reactive, but proactive and sustainable, rooted in a strong and relevant conceptual understanding.

While existing literature separately addresses participatory pathologies (Arnstein, 1969), elite capture (Platteau, 2004), and socio-technical systems (Trist, 1981), this article integrates these lenses to formulate a unified explanatory framework for digital planning reform. We proffer two central theoretical propositions:

- The Technocratic-Political Decoupling Proposition: Digital tools in Indonesia fail not due to technical inadequacy, but because they do not account for the structural decoupling between technocratic planning (Bappeda) and political budgeting (DPRD).
- The Deliberative Evidence Proposition: Meaningful participation in high-power distance societies requires a "socio-technical equalizer"—specifically, the democratization of simulation capabilities—to transition citizens from tokenistic consultation to evidence-based negotiation.

By synthesizing this perspective, this article contributes a novel "Deliberative Digital Twin" framework that advances smart governance theory beyond administrative efficiency toward democratic deepening.

Pathologies of Participation: From Arnstein's Ladder to Elite Capture

The classic framework for analyzing participation is Arnstein's (1969) "ladder of citizen participation." Arnstein argued that many participation practices are actually illusions, far from meaningful participation and citizen empowerment. She classified participation into eight rungs, ranging from non-participation to full citizen control.

Musrenbang, in practice, is often trapped on the lower rungs. At the low levels, Manipulation and Therapy (non-participation), Musrenbang can be used by the government to persuade citizens to accept pre-decided projects. However, what is more common is the trap at the level of tokenism. In this scenario, citizen aspirations are not genuinely heard or accommodated but merely serve as a pseudo-legitimacy for decisions already made. Citizens feel they have participated when, in essence, they have only been objects of a predetermined process. Tokenism itself consists of three rungs: Informing, Consultation, and Placation.

At the Informing level, citizens are only told about plans or projects to be implemented without any room to influence the decision. At the Consultation level, the government may ask for input from citizens, but this input has no binding power and is often merely ceremonial. Finally, at the Placation level, there are citizen representatives in the decision-making forum, but they are in a minority position and their voices are easily ignored by more dominant forces. In the context of Musrenbang, community representatives who attend often only function as a rubber stamp or lack significant bargaining power to change the direction of policies or projects already proposed by the government. This creates the impression of participation, whereas in reality, citizens are only given a "seat" at the discussion table without any real power to direct or reject policies.

- Informing: The government provides information (e.g., budget ceilings) in a one-way manner, often in formats that are difficult to understand (thick documents, technical jargon), without providing channels for meaningful feedback.

- Consultation: Musrenbang forums are held, surveys are distributed, and proposals are collected. However, there is no guarantee that this input will be seriously considered. This process often becomes a ritual to check the 'public participation' box.
- Placation: Some community representatives (e.g., community leaders deemed 'cooperative') are invited to sit on formulation teams or committees, but they have a minority vote and little power to influence the final decision.

Although Arnstein's model is criticized for its binary and linear view of power (Tritter & McCallum, 2006), it remains a powerful diagnostic tool for identifying pseudo-participation. This pathology creates fertile ground for elite capture. Asymmetries of information and power allow well-organized and well-connected groups to dominate the process, ensuring that public resources are allocated to their interests, not to broader collective needs (Platteau, 2004). This is a well-documented problem in community-driven development programs worldwide, including in Indonesia (Olken, 2007).

Deliberative Democracy

As a normative goal, we turn to the theory of Deliberative Democracy. Unlike aggressive democratic models that simply aggregate preferences, the deliberative model emphasizes the process of public reasoning. In this framework, the legitimacy of political decisions stems not merely from majority support, but is born from free, equal, and rational deliberation. In such deliberation, what prevails is the 'forceless force of the better argument,' not the dominance of political or economic power (Dyrzek, 2002; Habermas, 2015).

At the core of this theory is the concept of communicative action (Habermas, 1985). It distinguishes between two types: strategic action (aimed at achieving personal success, like winning a project for one's group) and communicative action (aimed at achieving mutual understanding). Strategic action is instrumental, where individuals or groups act to achieve personal or group success. In contrast, in communicative action, the focus is on the validity of claims, the clarity of arguments, and the willingness to reach consensus through dialogue.

Habermas also introduced the idea of the 'ideal speech situation,' which is a condition where all participants have an equal opportunity to speak, challenge claims, and propose arguments, free from coercion. In this situation, all participants have an equal chance to speak, make claims, challenge arguments, and propose ideas without any coercion or domination. This condition implies equal access to information, the absence of power hierarchies that inhibit expression, and a shared commitment to seeking truth through rational argumentation.

However, in the reality of Musrenbang, this situation is far from ideal. Participants are not equal; some have access to data and expertise, while others do not. Some speak with political authority, while others speak with a barely audible voice. The Deliberative Digital Twin aims to create conditions that approach this ideal speech situation by democratizing access to data and analytical tools, so that arguments can be evaluated based on their validity, not on who presents them.

Seeing this challenge, the "Deliberative Digital Twin" concept emerges as a promising innovation. Its goal is to create conditions that more closely approximate the ideal speech situation in the context of public participation. This is done by democratizing access to data and analytical tools. By providing a platform where relevant information is easily accessible to all parties and sophisticated analytical tools can be used transparently, the arguments presented in the deliberative process can be evaluated based on their validity and substantial weight, rather than on who presents them or their position of power. The hope is that this will foster a more inclusive, rational deliberation and ultimately produce more legitimate and sustainable decisions.

Socio-Technical Systems Perspective

The failure of e-Musrenbang demonstrates the danger of a technologically deterministic approach. To avoid the same mistake, we adopt a 'socio-technical systems' perspective. This theory, originating from the Tavistock Institute in the 1950s, states that every organization or work system consists of two interdependent subsystems (Baxter & Sommerville, 2011; Trist, 1981):

- Social Subsystem: This includes the human elements within a system. It involves the people involved, the organizational structure governing their interactions, the culture that shapes their values and norms, and the political and power dynamics that influence decision-making. These aspects are often abstract but have a significant impact on how the system functions.
- Technical Subsystem: This subsystem refers to the tools, technologies, processes, and work methods used to achieve organizational goals. This could be software, hardware, algorithms, standard operating procedures, or even the physical layout of the workplace.

The success of a system is not determined by optimizing one subsystem alone, but by the 'joint optimization' of both. This means that efforts to improve performance must be made simultaneously on both the social and technical aspects, not just focusing on one. Optimizing one subsystem without considering the other will only create imbalance and inefficiency.

E-Musrenbang failed because it optimized the technical subsystem while ignoring the social subsystem. E-Musrenbang overemphasized the optimization of the technical subsystem, particularly in the efficiency of data collection and input. The assumption was that by providing a sophisticated digital platform, the planning process would become more transparent and participatory. However, this assumption completely ignored the complexity of the social subsystem. Deeply rooted power dynamics, bureaucratic cultures resistant to change, and political resistance from actors who felt threatened by the new technology were all overlooked.

Ironically, instead of changing actor behavior, e-Musrenbang was adapted by actors within the social subsystem (especially political elites and bureaucrats) to serve their old objectives. The technology was used to maintain the status quo and the existing power relations framework, rather than to create substantive change. This shows that technology, without changes to the social and cultural structure, will only become a tool that reinforces the existing system.

Recognizing the lessons from this failure, the Deliberative Digital Twin concept is consciously designed as an intervention focused on the interface of these two subsystems. The Deliberative Digital Twin is not merely a technical tool. Instead, it is a comprehensively designed ecosystem to reshape the norms, interactions, and power relations within the social subsystem. This is done by changing how information is produced, shared, and debated within the system. Thus, the Deliberative Digital Twin seeks to create joint optimization, ensuring that technological progress goes hand-in-hand with the social transformation needed to achieve the greater goal.

Proposed Conceptual Framework: The Deliberative Digital Twin

This model is designed as a socio-technical ecosystem with a multi-layered architecture aimed at transforming raw data into interactive, evidence-based deliberative insights. This model consists of four integrated layers (Figure 1), comprising: (a) Layer 1: Integrated Data Foundation, (b) Layer 2: Visualization Platform; (c) Layer 3: Analysis and Simulation; and (d) Layer 4: Participation Interface.

Layer 1: Integrated Data Foundation

This layer is the backbone that absorbs and harmonizes data from various silos. Without a solid data foundation, the entire model will collapse. The key is interoperability supported by the One Data Indonesia (SDI) policy. This layer is a vital foundation that serves as the main backbone, tasked with absorbing and aligning data flows from various different sources or "silos." Without this robust and integrated data foundation, the entire model or system built upon it will be vulnerable and potentially collapse. This stage is not a prerequisite, but a political intervention in itself.

The key to success in creating a strong data foundation lies in interoperability. This concept means the ability of different systems and components to work together, share information, and effectively use the information that has been exchanged. This interoperability is specifically supported and regulated by the One Data Indonesia (SDI) policy. The SDI policy is designed to ensure that data produced by various government agencies and public institutions in Indonesia becomes uniform, easily accessible, and shareable, thereby avoiding data duplication and improving the quality of data-driven decision-making. Thus, this layer not only collects data but also ensures it can communicate and collaborate efficiently, in line with the SDI vision.

- Data Sources: The development of a comprehensive and reliable Geographic Information System (GIS) heavily depends on the availability and quality of various geospatial data sources. These data can be categorized by origin, format, and characteristics, covering a broad spectrum to meet diverse spatial analysis needs.
    - Authoritative Geospatial Data: This is the primary foundation of GIS issued by official government agencies with high accuracy and precision. Examples include (a) Base Maps from the Geospatial Information Agency (BIG), providing a spatial reference framework of topography, administrative boundaries, hydrography, and other basic geographical features that serve as the main reference for all spatial data; (b) Parcel Data from the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN), providing detailed information on land ownership, parcel boundaries, and land legal status, crucial for spatial planning and asset management.
    - Sectoral Data from Regional Work Units (OPD): Each OPD has specific data relevant to its tasks and functions, which, if integrated spatially, will enrich GIS analysis. Examples: (a) Education Agency, such as data on school locations (elementary, junior high, high school/vocational), number of students per school, support facilities, and teacher distribution. This information is important for analyzing educational accessibility and planning new educational facilities; (b) Health Agency, such as data on health facility locations (health centers, hospitals, posyandu), disease prevalence data per region, immunization coverage, and environmental sanitation information. This data is vital for mapping disease spread, planning health services, and mitigating outbreaks; and (c) Public Works (PU) Agency, such as data on the road network (road type, condition, width), drainage network data (channel locations, capacity), and other public

infrastructure information like bridges and dams. Important for connectivity analysis, transportation planning, and hydrological disaster mitigation.

- Spatial Planning Documents: Spatial planning documents such as the Regional Spatial Plan (RTRW) and Detailed Spatial Plan (RDTR) that have been georeferenced become spatial policy layers. This allows for overlaying policies with existing conditions on the ground, aiding in decision-making related to permits, regional development, and spatial law enforcement.
- Real-Time Data (if available): The use of sensor technology and the Internet of Things (IoT) enables real-time data collection that can provide dynamic information about a condition. Examples: (a) Traffic Sensors, providing data on traffic density, vehicle speed, and road incidents; (b) Air Quality Sensors, monitoring air pollution levels at various locations; and (c) Water Level Sensors, providing early warnings of potential floods. This real-time data is very valuable for monitoring, risk mitigation, and rapid response to specific events.
- Volunteered Geographic Information (VGI): is data collected and shared by citizens via digital platforms. VGI provides a "bottom-up" perspective and often includes details not available in official data. Examples: (a) Damaged Road Reports, with geotags and photos, providing information on the location and condition of roads needing repair; (b) Flood-Prone Points, reports from citizens experiencing or seeing puddles, helping to map flood-prone areas more accurately; and (c) Slum Areas, visual and spatial information from citizens about areas needing development intervention. VGI becomes an important complement to authoritative data, especially on issues requiring community participation.

- Data Management: After various data are collected, the next crucial step is effective data management to ensure the integrity, consistency, and usability of the data in the GIS.
  - Centralized Geospatial Database (PostGIS): The use of a spatial-object relational database management system like PostGIS (a spatial extension for PostgreSQL) is highly recommended. PostGIS can store and manage spatial data (point, line, polygon geometries) and non-spatial data (descriptive attributes) in an integrated platform. Its advantages include: (a) Scalability, capable of handling large volumes of data; (b) Complex Spatial Queries, supporting various spatial operations like buffer, overlay, intersection, and other complex analyses; (c) Multi-User Access, allowing many users to access and manipulate data simultaneously; (d) Easy Integration, compatible with various commercial and open-source GIS software.
  - ETL (Extract, Transform, Load) Process: Data from various sources often come in different formats, structures, and standards. A systematic ETL process is necessary to overcome this heterogeneity: (a) Data Cleaning, deleting data, fixing typos, handling missing or invalid values; (b) Data Harmonization, standardizing attributes, ensuring consistency of projections and geodetic datums between data layers; (c) Format Conversion, changing data to a format suitable for the geospatial database; (d) Aggregation/

Disaggregation, combining or splitting data according to analysis needs.

- Standard Data Schema according to SDI (Spatial Data Infrastructure): It is important to develop a clear and consistent data schema, following the principles of Spatial Data Infrastructure (SDI). This includes: (a) Metadata Definition, each data layer must have complete metadata (source, creation date, accuracy, projection, attribute description) to be easily understood and reused; (b) Standardization of Geographic Objects, uniformity in object representation (e.g., all roads represented as lines, all buildings as polygons); (c) Consistent Attributes, use of the same attribute names and data types for similar information across different datasets, (d) Data Versioning, a system for tracking data changes and updates. Applying SDI principles ensures data can be shared, accessed, and operated interoperably by various parties, maximizing the value of the geospatial data investment.

Layer 2: Core Model & Visualization Platform
This layer transforms data into an interactive virtual representation of the city, an Urban Digital Twin (UDT). This is the main container where various deliberation and decision-making processes can take place spatially and visually.

- Platform: The UDT will be implemented as a web-based platform, utilizing advanced 3D visualization technologies such as Cesium or Mapbox GL JS. This technology choice is crucial as it supports massive-scale 3D city visualization while ensuring high accessibility through standard browsers without requiring expensive or specialized hardware specifications. For efficiency, the 3D city model will be built procedurally. This means the model will be automatically generated from more easily obtainable 2D data, such as building footprints and elevation data, rather than manually building every 3D object. This approach allows for rapid updates and better scalability.
- Function: The core function of the UDT platform is to provide a virtual "sandbox" that allows users to visually and spatially explore various policy scenarios. In this context, the UDT transforms the abstraction of a budget list or policy proposal into a concrete intervention whose impact can be visualized on the city map. The Geodesign principle (Steinitz, 2012) will be the main guide in designing the user interface. Geodesign is a methodology that integrates the geographic design process with instant feedback from impact analysis. This means when a policy change or intervention is proposed in the UDT, the system will immediately display its potential spatial impact, allowing planners and stakeholders to make more informed decisions.

- Concrete examples of user interaction in the UDT include the ability to click on specific objects on the map, which then reveals rich and relevant layers of information.
  - School: When a user clicks on a school icon on the map, the UDT system will display a series of crucial demographic and operational data. This includes the current number of students, which can be categorized by education level (e.g., kindergarten, elementary, junior high, high school) or age; the student-teacher ratio, which indicates teaching quality and teacher workload; facility conditions, including data on building age, maintenance status, availability of support facilities like labs, libraries, or sports fields, and information on accessibility for people with disabilities; and projections of future classroom needs, calculated based on population trends, birth data, and housing

development plans around the school area. This information is very helpful in planning educational budget allocations, determining strategic locations for new schools to meet growing population needs, or identifying schools that require renovation and facility upgrades.

- Road Segment: By clicking on a specific road segment, users can access detailed information vital for transportation infrastructure planning. The data displayed includes average daily traffic volume, which can be broken down by time (e.g., morning, afternoon, evening rush hours) or day of the week; the dominant types of vehicles, such as private vehicles, public transport, or logistics vehicles, which is important for understanding road use characteristics; road surface conditions, with indicators such as the level of damage (e.g., cracks, potholes, waves), repair needs, or the last maintenance schedule; and data related to congestion or accidents, including accident-prone spots, frequency of incidents, and main causes. This information is essential for planning road repairs, optimizing public transport routes, placing effective traffic signs or road markings, and developing policies to reduce congestion and improve traffic safety.

Thus, the UDT functions not only as a visualization tool that displays data in a geographical format but also as a dynamic collaborative platform. This platform allows stakeholders from various backgrounds—from city planners, transport engineers, education agencies, to the general public—to interact with city data intuitively. They can test various hypotheses about the impact of policy decisions, understand the spatial consequences of proposed interventions (e.g., construction of a new building, zoning changes, or addition of a bus lane), and explore "what-if" scenarios before these decisions are implemented in the real world. This supports a more participatory city planning process, where input from various parties can be integrated; more transparent, because data and analysis are openly available; and more evidence-based, because decisions are based on accurate data and in-depth analysis, not just assumptions or speculation.

Layer 3: Analytics & Simulation

This is the brain of the intervention, designed for contestation, not just optimization. This layer combines two complementary modeling methodologies to create a multi-scale understanding.

- System Dynamics (SD) Modeling: Used for macro-level analysis, modeling causal relationships and long-term feedback loops (Forrester, 1973; Sterman, 2002). SD excels at uncovering unintended and delayed consequences that may not be apparent at first glance, providing deep insights into system behavior over time.\
    - Example Scenario: Citizens propose the construction of a new traditional market. Local elites reject it, reasoning it will cause traffic congestion. The SD model can simulate this scenario. Market construction (investment) -> increases local economic activity (stock) -> increases resident income (stock) -> increases vehicle ownership (stock) -> increases traffic volume (flow) -> creates congestion (negative feedback). However, the model can also simulate balancing policies: market construction + road widening + parking management -> reduces congestion. This changes the debate from "yes/no" to "what if."
    - However, SD's advantages don't stop at problem identification. The model can also simulate balancing policies or mitigation interventions. For example, the model can show that by combining

market construction with strategic road widening and efficient parking management, the impact of congestion can be significantly reduced or even avoided. This approach fundamentally changes the debate from a binary "yes/no" choice to a more constructive discussion about "what if" or "what solutions are possible." This allows stakeholders to see various possibilities and formulate more comprehensive strategies.

- Agent-Based Modeling (ABM): Used for micro-level analysis, translating abstract policy impacts into human-scale experiences (Bonabeau, 2002; Gilbert, 2019). ABM works by simulating the behavior of autonomous "agents"—individuals, households, or other relevant entities—and then observing the macro-patterns that emerge from their dynamic interactions. Each agent has a set of behavioral rules and goals, and their interactions create the system's complexity.
    - Advanced Scenario Example: From the SD model, we know the market will attract 5,000 visitors per day. The ABM model can simulate the movement of these 5,000 agents from their homes (based on demographic data) to the market location. The result, visualized in the UDT, will show specifically which road segments will be severely congested at certain hours. This allows citizens and planners to discuss very specific solutions, such as "What if we make Jalan Merdeka one-way from 8-10 AM?" or "Where is the best location for a public transport stop?". This synergy makes the systemic impact personal and hard to ignore.
    - The results of the ABM simulation, often visualized through platforms like the UDT or similar, will show specifically which road segments are most likely to experience severe congestion at certain hours. This detailed information is very valuable as it allows citizens, city planners, and policymakers to discuss very specific and targeted solutions. For example, the discussion can shift to questions like: "What if we implement a one-way system on Jalan Merdeka from 8-10 AM to reduce build-up?" or "Where is the best location to build a new public transport stop to maximize market accessibility and reduce private vehicle use?"
    - The synergy between SD and ABM is the main strength of this approach. SD provides the big picture and understands the system dynamics as a whole, while ABM provides the micro-details that make the systemic impact personal, concrete, and hard to ignore. This combination allows for a holistic understanding from macro consequences down to the micro-level individual experience, encouraging more informed and collaborative decision-making.

Layer 4: Participation & Deliberation Interface

This is the bridge between the technology and the user, designed as a Progressive Web Application (PWA) that can be accessed on various devices. The PWA bridges the gap between technology and users. It is designed to offer a seamless and easily accessible experience across various devices, from smartphones to tablets and desktop computers. With this approach, the main goal is to ensure that the information and functionality provided can be reached by a wide audience, unhindered by hardware or operating system limitations.

- Key Features: (a) Interactive 3D Visualization, The platform offers dynamic and interactive 3D visualization, allowing users to explore and understand project proposals with unprecedented depth. This feature is designed to present complex information visually, making it easier to digest and analyze by all participants; (b) Simple Participatory Design Tools, One of the main innovations is an intuitive participatory design tool, allowing users to "draw" their proposals directly on the map. This tool empowers individuals, regardless of their technical background, to actively contribute to the planning and design process, fostering a sense of ownership and engagement; (c) Location-Based Deliberative Forums, Each proposal has its own discussion space, functioning as a location-based deliberative forum. This feature facilitates focused and contextual discussions, where users can interact, share perspectives, and debate the merits of various proposals directly and transparently; and (d) Comprehensive Transparency Dashboard, an integrated transparency dashboard tracks every proposal from initial submission to the final decision. This dashboard includes information on the reasons for rejection or acceptance, ensuring full accountability and providing clarity on the decision-making process.

- Objective: To level the deliberative playing field by giving all participants—regardless of their technical background—the ability to see, understand, and debate the merits of various proposals based on simulation evidence.
- Status and Scalability: It is important to clarify that the architecture presented here is conceptual and anticipatory. It represents a theoretical model designed to guide future software development and policy reform, rather than a report on an already operational system.

  Regarding scalability and cost, we acknowledge that Digital Twins are traditionally resource-intensive. To mitigate this, the proposed framework relies on a modular open-source stack (e.g., utilizing OpenStreetMap for base layers and Python-based Mesa for ABM simulations) rather than proprietary enterprise software. Furthermore, the procedural generation of 3D city models reduces the need for manual, labor-intensive modeling. This ensures that the framework remains financially viable for local governments in Indonesia with varying fiscal capacities (APBD), allowing for incremental adoption starting with key strategic districts before city-wide scaling.

Results and Discussion

As this is a conceptual reconfiguration of governance, the "results" presented here are forward-looking plausibility claims derived from the socio-technical analysis of Indonesia's political economy. We analyze the probable friction points and transformative potential of introducing the Deliberative Digital Twin into the existing Bappeda-DPRD ecosystem.

The implementation of this model is not merely a technical challenge, but a political maneuver. Its success depends on the ability to overcome the following barriers:

Political Barriers:

The local budgeting process is a product of negotiations between the technocratic power of the local government (represented by Bappeda) and the political power of the regional parliament (DPRD). Bappeda, with its technical expertise, tends to prioritize proposals that align with the Regional Medium-Term Development Plan (RPJMD) and performance indicators. Bappeda's priority is to ensure that every budget allocation contributes to achieving established performance indicators, such as infrastructure improvement, poverty reduction, or enhanced education quality. Their proposals are based on feasibility studies, demographic data, and economic projections, aiming for long-term development efficiency and effectiveness.

Conversely, DPRD members, as political representatives of the people, have strong electoral incentives. They tend to champion "pet projects" that are conspicuous and provide direct benefits to their constituent base. Such projects often take the form of physical construction like monuments, city gates, or public facilities that are easily seen and identified as the work of the council member. Although these projects may be popular with voters and fulfill campaign promises, they are often systemically inefficient. This means the costs incurred may not be proportional to the broad benefits provided to the community as a whole, or more pressing needs are overlooked (Kuncoro, 2018).

In this context, the emergence of the "Deliberative Digital Twin" concept offers an innovative solution to challenge this imbalance. The Deliberative Digital Twin is a digital simulation model that can visualize and calculate the opportunity cost of each project proposal. For example, this simulation can transparently show that the budget for building a grand monument or city gate, often a popular proposal from politicians due to its visibility, could actually be allocated to repair 50 km of damaged neighborhood roads. This road repair, though less "grand," would provide direct and broad benefits to thousands of citizens who use it daily, improving connectivity, and supporting the local economy.

This exposure of opportunity costs directly highlights the inefficiency of budget allocations and forces decision-makers to consider the broader impact of each choice. With clear data and visualization, the public and policymakers can concretely see what is lost when the budget is allocated to less strategic projects. This will inherently trigger resistance from elites who benefit from an opaque and unaccountable budgeting process. Parties whose interests are threatened by this transparency may try to discredit the Deliberative Digital Twin model as an unaccountable or overly complex "black box" for the public to understand. They might argue that the model does not consider non-technical aspects or political needs. However, the Deliberative Digital Twin's ability to facilitate a robust, data- and evidence-based dialogue has great potential to foster a more transparent, accountable, and public-interest-oriented budgeting process, ultimately shifting priorities from "pet projects" to projects with more significant and sustainable social and economic impacts.

Institutional Barriers:

Bureaucracy in Indonesia is often characterized by a closed, hierarchical, and change-resistant culture, a legacy of the New Order era (Utomo, Ridwan Maksum, & Kurniawan, 2023). In this context, transparency is often not seen as a fundamental value or a tool for improvement, but as a threat that could potentially expose weaknesses or improper practices.

Resistance to transparency efforts or the use of new technologies like open data platforms can manifest in various ways, from overt rejection to more subtle and disguised forms. One common form of resistance is through what is called "weaponized incompetence." This means officials or bureaucrats may intentionally feign technical inability or ignorance as a reason to delay or thwart transparency initiatives. For example, they might state that existing data is invalid or unreliable, that the analysis model is too complicated to implement, or that the local government lacks the adequate technical capacity to manage the new digital platform.

Furthermore, resistance can also be seen in passive-aggressive actions. Officials might delay providing crucial data, question the validity of any simulation or analysis results that do not align with their preferences or agendas, or even blatantly ignore the transparency platform that has been provided. They might continue to make decisions as usual, without integrating information or input from the platform, as if it did not exist.

Overcoming this deep-seated inertia and resistance requires a comprehensive and multidimensional approach. More than just technical training, which may only scratch the surface of the problem, strong and sustained advocacy is needed to change the bureaucratic mindset and culture. It is also essential to get full support from regional leaders or the head of the region (often referred to as a champion), who can be the driving force for change and provide legitimacy for the transparency initiative. Finally, a clear and rapid demonstration of the value of implementing transparency is crucial. This means showing concretely how transparency can improve efficiency, accountability, and, ultimately, the quality of public services, so that its benefits can be directly felt and encourage wider adoption. Without these three elements, efforts to promote transparency in Indonesia's bureaucracy will continue to face significant challenges.

Data Barriers:
Although Presidential Regulation (Perpres) Number 39 of 2019 concerning One Data Indonesia (SDI) has provided a strong and crucial legal foundation for data standardization and integration, its implementation at the regional level still faces serious challenges that cause inequality. One of the most prominent obstacles is the phenomenon of "sectoral egos" among Regional Work Units (OPD). Each OPD often tends to hoard its own data, reluctant to share or integrate it with other work units. This is exacerbated by the absence of uniform data standards. For example, data on region names and codes can vary between agencies, creating significant inconsistencies. Furthermore, the lack of comprehensive metadata worsens this problem as it is difficult to understand the origin, quality, and relevance of the data without adequate contextual information (Hasnita & Salomo, 2025).

In the context of Digital Twin development, which is highly dependent on the availability of high-quality data, the data collection and cleaning process will become a political intervention in itself. It will directly force various institutions to address their established "data silos." Without accurate, complete, and standardized data, the simulation and analysis results produced by the Digital Twin will tend to be invalid, following the "garbage in, garbage out" principle. This condition will fundamentally undermine the credibility and reliability of the entire Digital Twin system, rendering it ineffective for decision-making.

Therefore, it is crucial that the initial phase of a Digital Twin development project must include a comprehensive data audit. This audit not only serves to identify data gaps and inconsistencies but must also be accompanied by strong advocacy for data governance at the local level. Good data governance includes establishing clear data standards, efficient data-sharing mechanisms, and policies that support collaboration among OPDs, ensuring that data can be accessed and utilized optimally to support regional development.

Social Barriers:
Relying exclusively on individual digital access will exacerbate existing social disparities. The digital divide in Indonesia is not merely a problem of hardware availability, but also includes the aspect of digital literacy, which is still low, especially among the elderly, women in some regions with limited access, and low-income communities (APJII, 2023). This condition highlights the urgency of a more comprehensive approach.

Therefore, the implementation of digitalization programs must adopt a hybrid approach that integrates online and offline solutions. In addition to providing an accessible online platform, it is crucial to establish public access kiosks in strategic communal spaces, such as sub-district offices, community halls, or community centers. These kiosks must be equipped with adequate digital facilities and accompanied by trained digital facilitators.

The role of facilitators in this context is crucial and multifaceted. They not only function as technology "translators" who bridge the understanding gap between technology and the general public, but also as mentors who help citizens formulate the concrete problems they face into simulation scenarios on the digital platform. Furthermore, facilitators have the unique capacity to ensure that the voices from the most vulnerable groups—who are often marginalized in the development narrative—are not only heard but also amplified with data and evidence generated from their interaction with the platform. Thus, this hybrid approach not only increases access but also empowers the community through active and inclusive participation in the digital ecosystem.

Evaluation Methodology & Roadmap

Although Presidential Regulation (Perpres) Number 39 of 2019 concerning One Data Indonesia (SDI) has provided a strong and crucial legal foundation for data standardization.

To credibly measure the intervention's impact, we propose a quasi-experimental mixed-methods design. This approach is chosen due to the unique characteristics of the intervention, which does not allow for full randomization but still requires strong evidence of causality.

- Design: A comparative case study comparing a "treatment" city/regency (adopting the Digital Twin) with a "control" city/regency that is comparable in terms of demographics, fiscal capacity, and political dynamics (using traditional Musrenbang) over several budget cycles (minimum 2-3 years).
- Quantitative Analysis: Tracking metrics before and after the intervention. This could include: (1) Spatial analysis of budget allocations using indices like the spatial Gini to measure equity; (2) The success rate of proposals from marginal groups (identified through socio-economic data) vs. elite groups; (3) Content analysis of planning documents (meeting minutes, RKPD) to measure the frequency of using data- and simulation-based arguments versus opinion- or interest-based arguments.
- Qualitative Analysis: Crucial for understanding "why" and "how" changes occur. This includes: (1) In-depth semi-structured interviews with key stakeholders (Bappeda planners, DPRD members, CSO facilitators, community leaders, ordinary citizens) to capture their perceptions, strategies, and experiences; (2) Ethnographic observation in Musrenbang forums (both platform-facilitated and traditional) to document changes in deliberation quality, power dynamics, and the use of evidence; (3) Stakeholder analysis to map influence networks and resistance or adaptation strategies from elites.

Ethic and Algorithmic Governance

Beyond political and technical barriers, the deployment of a Deliberative Digital Twin introduces significant ethical challenges. There is a risk of "algorithmic bias," where the assumptions embedded in the System Dynamics or ABM models inadvertently favor certain socioeconomic outcomes. To prevent the "black-boxing" of policy, this framework mandates Open Algorithmic Governance: the code and variables governing the simulations must be open-source and subject to independent audit by civil society and academia. Furthermore, strict data privacy protocols must be established to ensure that the granular data required for Agent-Based Modeling does not infringe upon citizen privacy, utilizing data aggregation and anonymization techniques compliant with Indonesian privacy laws.

Conclusions

This article has argued that the stagnation of Indonesia's Musrenbang cannot be solved by digitalization alone, but requires a fundamental restructuring of the deliberation ecosystem. The proposed Deliberative Digital Twin makes three distinct contributions:

- Theoretical Contribution: It offers an integrated socio-technical framework that explains how simulation technologies can bridge the gap between technocratic rationality and political legitimacy, challenging the binary view of "expert" vs. "citizen" knowledge.
- Methodological Contribution: It proposes a novel architecture combining macro-level System Dynamics with micro-level Agent-Based Modeling, moving participatory planning methods from static mapping to dynamic impact forecasting.
- Practical Contribution: It provides a roadmap for local governments to transition from "tokenistic ritualism" to "evidence-based negotiation," specifically addressing the Bappeda-DPRD power asymmetry by making opportunity costs transparent to the public.

While the implementation faces substantial political resistance and institutional inertia, this model charts a necessary evolutionary path for smart governance in Indonesia—one that prioritizes democratic empowerment alongside administrative efficiency.

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