Participatory AI Governance for Smart Cities and Sustainable Infrastructure

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Keywords

Participatory Governance; Smart Cities; Sustainable Infrastructure; Stakeholder Engagement; AI Governance; Digital Twins; Public Trust

ABSTRACT

Smart cities and sustainable infrastructure increasingly rely on artificial intelligence, connected sensors, digital twins, and automated decision systems. These technologies can improve energy efficiency, maintenance, mobility, and service delivery, but they also create risks related to surveillance, exclusion, cybersecurity, opacity, and concentrated institutional power. This review examines participatory AI governance as a missing element in the development of sustainable digital infrastructure. It builds on a systematic synthesis of 95 high-quality studies and governance frameworks covering the period from 2020 to mid-2025. The source analysis found that privacy, ethics, regulation, and accountability dominate the literature, while citizen participation, stakeholder engagement, and smart-city governance remain comparatively isolated. Technical and legal themes often form one cluster, ethical themes another, and participation a peripheral cluster with weak links to mainstream control design. The article argues that sustainable AI governance must combine engineering assurance with democratic involvement. It reviews participation across the AI lifecycle, from problem definition and data collection to deployment, monitoring, appeal, and retirement. It also applies the discussion to digital twins, structural health monitoring, energy management, transport, and public-service platforms. A practical participation-and-assurance model is proposed, linking stakeholder input to decision rights, technical controls, evidence, and public reporting. The review concludes that participation is not an optional communication exercise; it is a source of risk knowledge, legitimacy, and long-term system resilience.

Introduction

Artificial intelligence is becoming part of the operating fabric of cities and infrastructure. Sensors monitor traffic, buildings, utilities, and public spaces. Digital twins model physical assets and support maintenance. AI forecasts energy demand, directs inspections, identifies anomalies, and helps allocate services. These applications can improve efficiency and resilience, which makes them attractive to governments and infrastructure operators.

The same systems can reshape public life in less visible ways. Data collection may expand surveillance. Automated priorities may favour areas with better data. Complex platforms may transfer decision power to vendors. Residents may not know when AI is used or how to challenge an outcome. Groups with limited digital access may be excluded from consultation and service design. A technically successful project can therefore fail socially or politically.

Governance research recognises ethics, privacy, regulation, and accountability, but participation receives less consistent attention. In the supplied source review, citizen participation and stakeholder engagement appeared at the edge of the governance network rather than at its centre. Smart-city and Internet of Things topics also formed a relatively separate cluster. This pattern suggests that public involvement is often treated as an additional social issue instead of a core part of risk management and system design.

This review argues that participatory governance improves both legitimacy and technical quality. Residents, workers, engineers, service users, and community organisations hold knowledge that may not appear in datasets. Their involvement can reveal harmful assumptions, missing use cases, practical constraints, and unequal consequences before they become embedded in infrastructure.

Review Scope and Evidence

The article is a structured narrative review based on the supplied systematic study of AI governance risk and cybersecurity frameworks. The source research retained 95 high-quality studies and frameworks after screening and quality appraisal. Its co-occurrence network identified distinct clusters around privacy, security, and regulation; ethics, transparency, and accountability; participation and inclusion; and smart governance or Internet of Things applications.

The participation cluster was peripheral, indicating limited integration with mainstream governance. The framework comparison also showed stronger maturity in privacy and ethics than in implementation, customisation, resilience, and participation. The present review reorganises those findings around smart cities and sustainable infrastructure. It focuses on how participatory methods can be combined with technical controls, risk tiering, and evidence rather than treated as public relations.

Why Participation Matters

Participation improves problem definition. Institutions may begin with a technological solution and search for a problem it can address. Communities can question whether automation is necessary, identify alternative interventions, and clarify which outcomes matter. This prevents resources from being committed to systems that are efficient in narrow terms but poorly aligned with public need.

Participation reveals distributional effects. Infrastructure decisions rarely affect everyone equally. A transport optimisation model may reduce average travel time while worsening access for a low-income neighbourhood. Energy controls may improve efficiency while reducing comfort for older people or people with disabilities. Predictive maintenance may prioritise assets in areas where sensors are newer or more reliable. Residents and frontline professionals can identify these patterns.

Participation strengthens data governance. People can explain why particular data are sensitive, how collection changes behaviour, and which secondary uses feel unacceptable. Community input may lead to shorter retention, local processing, aggregation, or restrictions on data sharing. It can also expose gaps where some groups are missing from the data.

Participation supports accountability. Public review can clarify who owns the system, which decisions remain human, how complaints are handled, and what evidence will be published. It creates pressure for institutions to explain trade-offs rather than presenting AI as neutral or inevitable.

Finally, participation contributes to resilience. Systems designed with local knowledge are more likely to fit operational reality and retain cooperation during disruption. Trust based on genuine involvement can improve reporting of errors and acceptance of necessary changes.

Participation Across the AI Lifecycle

At the agenda-setting stage, institutions should engage affected communities before defining the use case. The discussion should cover the problem, alternatives, expected benefits, possible harms, and whether AI is appropriate. Participation should include groups likely to bear risk, not only digitally confident or already organised stakeholders.

During data design, stakeholders can review collection methods, consent, purpose, retention, access, and representativeness. Domain professionals can identify measurements that are misleading or context-dependent. Communities can highlight surveillance concerns and secondary uses that designers may overlook.

During development and testing, participatory methods include workshops, scenario testing, usability studies, citizen juries, professional review panels, and red-team exercises involving social as well as technical harms. Participants should see realistic examples and have enough information to offer meaningful criticism.

Before deployment, the institution should publish an accessible summary of purpose, data, safeguards, limitations, and challenge routes. High-risk projects may require formal public consultation or independent oversight. Deployment conditions can incorporate commitments made during engagement.

After deployment, participation continues through complaints, appeals, community monitoring, user feedback, and periodic review. Institutions should report incidents, significant changes, and outcomes. Retirement or replacement also deserves consultation when the system has become embedded in essential services.

Lifecycle stage	**Participation method**	**Governance value**	**Evidence to retain**
Problem definition	Community workshops, professional panels alternatives assessment	Clarifies need, harms affected groups, and non-AI options	Stakeholder map issue log, decision rationale
Data and design	Privacy consultation data walks, co-design sessions	Identifies sensitive data missing groups, and acceptable boundaries	Data decisions consent approach design changes
Testing	Scenario exercises usability testing, social red teaming	Reveals practical failure unequal effects, and misleading explanations	Test results participant feedback, remediation record

Lifecycle stage	Participation method	Governance value	Evidence to retain
Deployment	Public notice, citizen panel, independent review	Supports legitimacy, clear conditions, and challenge routes	Published summary, approval conditions, response plan
Operation and review	Complaint channels, community monitoring, periodic forums	Detects emerging harm, drift, and changed expectations	Complaint trends, monitoring reports, meeting outcomes

Smart-City and Infrastructure Applications

Digital twins combine data and models to represent physical assets or urban systems. They can support planning and maintenance but may also centralise extensive information about buildings, movement, or resource use. Governance should define who can access the twin, which decisions it supports, how uncertainty is represented, and whether affected communities can challenge assumptions.

Structural health monitoring uses sensors and AI to detect possible damage. Public safety benefits are significant, but false reassurance or missed warnings can be serious. Engineers, operators, emergency services, and users should contribute to threshold design and response procedures. Human responsibility for final safety decisions must remain clear.

Smart energy systems use AI to manage demand, storage, and distributed generation. Participation can reveal how automated controls affect households, businesses, and vulnerable users. Privacy-preserving aggregation and opt-out or override mechanisms may be needed. Public reporting can show whether efficiency gains are shared fairly.

Transport systems may optimise traffic or public transit using location and behavioural data. Engagement should include people with disabilities, low-income travellers, cyclists, pedestrians, and communities affected by rerouting. Average efficiency should not be the only measure; access, safety, affordability, and environmental impact also matter.

Public-service platforms may integrate data across agencies. Integration can improve coordination but increase surveillance and function creep. Participatory governance can establish boundaries, acceptable uses, retention periods, and appeal rights before the platform becomes difficult to change.

Integrating Participation with Technical Assurance

Participation is strongest when linked to decision rights and controls. Feedback should not disappear into a consultation report. Each significant issue should be assigned an owner, assessed for risk, and connected to a design change, mitigation, or documented explanation. The evidence layer should show what was raised and how the institution responded.

Risk tiering can determine the intensity of participation. Low-risk internal tools may require user testing and staff consultation. Medium-risk public systems may require stakeholder workshops and published information. High-risk systems affecting rights, safety, or essential services need broad engagement, independent review, appeal routes, and continuing public oversight. Critical infrastructure may require formal representation of affected groups in governance bodies.

Technical assurance remains necessary. Participation cannot replace cybersecurity testing, privacy engineering, validation, or resilience planning. It improves those processes by identifying realistic threat scenarios and social consequences. For example, community knowledge may reveal that a data-sharing arrangement creates risks not visible in a technical architecture diagram. Frontline staff may identify how workers will bypass a model under pressure.

The principles-controls-evidence model can incorporate participation directly. Participation is a principle of inclusive governance. Controls include stakeholder mapping, accessible consultation, co-design, complaint routes, and public review. Evidence includes participant selection, issues raised, changes made, reasons for rejection, and ongoing outcome data.

Inclusion, Representation, and Power

Participation can reproduce inequality if it relies on people with time, confidence, digital access, or institutional connections. A credible process should identify groups that are affected but unlikely to volunteer. Support may include translation, accessible venues, compensation, childcare, remote and offline options, and partnerships with trusted organisations.

Representation does not mean that every participant must agree. The purpose is to surface perspectives, conflicts, and trade-offs. Institutions should avoid presenting consultation as consensus when disagreement remains. Minority concerns may deserve action even if they are not numerically dominant, especially where potential harm is severe.

Power must be addressed openly. Participants need to know which decisions they can influence. Engagement that asks for feedback after procurement and design are complete creates frustration. Early participation provides greater opportunity for change. Independent facilitation or oversight can help when trust is low.

Vendor power also matters in smart-city projects. Proprietary systems may limit public understanding and local control. Contracts should protect access to documentation, audit rights, data ownership, interoperability, and exit options. Participation should inform procurement requirements, not only the public launch.

Sustainability, SDG 9, and Long-Term Governance

Sustainable infrastructure must be resilient, inclusive, and capable of adaptation. Participation contributes by aligning systems with real needs and identifying social risks that can undermine long-term use. It also supports accountability for environmental claims. An

AI system that saves energy in one part of a service but increases resource use, exclusion, or surveillance elsewhere may not be sustainable.

Sustainable Development Goal 9 links innovation with resilient infrastructure and inclusive industrial development. Participatory AI governance supports this goal by connecting technical innovation with public value. It helps ensure that smart infrastructure does not benefit only well-served communities or create hidden burdens for others.

Long-term governance should review whether promised benefits were achieved, who received them, and what unintended effects emerged. Public reporting can include performance, incidents, energy and resource use, complaints, fairness outcomes, and major changes. These measures make sustainability a continuing responsibility rather than a claim made at project approval.

Limitations and Future Research

The literature provides strong arguments for participation but less evidence about which methods produce measurable changes in AI design and outcomes. Some studies focus on willingness to use technology or general trust rather than evaluating whether systems are safer, fairer, or more accountable.

Future research should compare consultation, co-design, citizen assemblies, community monitoring, and other methods across different infrastructure contexts. It should examine representation, cost, decision influence, and long-term effects. Researchers should also develop tools that help non-specialists understand models, uncertainty, privacy, and trade-offs without oversimplification.

More work is needed on governance at regional and cross-border scale. Infrastructure systems often connect multiple agencies, vendors, and communities. Participation must therefore address who has authority, how conflicts are resolved, and how local concerns are protected within large platforms.

Conclusion

Participatory governance is an essential part of trustworthy and sustainable AI. The reviewed literature shows that citizen involvement and smart-city governance remain less integrated than privacy, ethics, regulation, and technical risk. This separation weakens both legitimacy and system quality. Participation contributes practical knowledge throughout the AI lifecycle. It improves problem definition, data governance, testing, deployment conditions, monitoring, and correction. Its value increases when feedback is linked to decision rights, controls, owners, and auditable evidence. It should complement technical assurance, not replace it. Smart cities and critical infrastructure shape daily life over long periods. Decisions made during early design can become difficult to reverse. By involving affected people and professionals before systems are fixed, institutions can build infrastructure that is not only intelligent, but also inclusive, accountable, secure, and resilient.

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