



Transformative Environmental Governance for Addressing Wicked Problems in the Iranian Context: Institutional and Policy Dynamics in Tehran

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ABSTRACT

Air pollution in the Tehran megacity constitutes a persistent and politically contested environmental wicked problem in the Middle East, marked by uncertainty, multi-scalar causality, and entrenched institutional and political-economic lock-ins. Despite decades of regulatory reforms and technological upgrading, air quality outcomes remain unstable, revealing structural limitations of centralized, command-and-control governance. Fragmented sectoral mandates, weak inter-organizational coordination, selective enforcement, and limited collective learning capacity have constrained responses to the nonlinear and conflictual dynamics of urban pollution. This qualitative case study examines how a transformative environmental governance framework clarifies the institutional, cognitive, and relational conditions required to confront such intractable challenges under constrained political openness and asymmetric power relations. Drawing on systematic analysis of policy and legal documents, semi-structured interviews with governmental, municipal, scientific, and civil-society actors, and policy process tracing, the study reconstructs the evolution of Tehran's air pollution regime. It identifies structural barriers, path dependencies, regime-stabilizing incentives, and power asymmetries that sustain policy inertia. Findings reveal four interdependent yet politically contingent leverage points: adaptive institutional redesign to strengthen cross-sectoral integration; multi-actor co-production across state, municipal, market, and civil domains; reflexive social learning to harmonize problem framings across scales; and anticipatory policy innovation grounded in foresight and precaution. However, these mechanisms remain fragile due to centralized authority, energy subsidy regimes, and protection of regime-affiliated economic interests. The article proposes a conditionally transferable model of transformative environmental governance, specifying enabling conditions and structurally reinforced failure dynamics, and outlining politically feasible strategies for metropolitan air quality reform in restrictive political contexts.

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INTRODUCTION

Air pollution in Tehran exemplifies a critical governance challenge in rapidly urbanizing megacities of the Global South, where environmental degradation is exacerbated by weak regulatory capacity and political-economic constraints (Yazdanibakhsh et al., 2019; Qu et al., 2025; Ghahremanlou & Ghahremanlou, 2025). Tehran's PM_{2.5} and PM₁₀ concentrations consistently exceed WHO (2021) guidelines due to a convergence of geographic, technical, and structural factors—including thermal inversions, aging vehicles, industrial emissions, and fossil fuel subsidies—all embedded within a political economy that prioritizes stability over environmental enforcement (Alizadeh-Choobari et al., 2016; Taghizadeh et al., 2023).

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Despite repeated mitigation efforts, durable improvement remains elusive, reflecting deeper institutional failures in Iran's centralized and fragmented governance system (Nadrian & Pirehbabi, 2025; Yousefi et al., 2025). Sectoral fragmentation, rigid command-and-control mechanisms, and regime-affiliated interests produce incoherent implementation and structural lock-ins that resist reform (Attiq et al., 2024). Tehran's pollution thus represents a wicked problem—marked by indeterminacy, feedback loops, and contested values—that eludes linear, technocratic solutions (Rittel & Webber, 1973; Head, 2023; Nasehi & Nohegar, 2025).

Transformative governance—emphasizing reflexivity, coordination, and adaptation—offers a conceptual lens for addressing such complexity (Evans et al., 2016). However, its applicability in authoritarian or hybrid contexts remains underexplored, particularly where institutional trust is low and political survival strategies constrain change (Lemos & Agrawal, 2006; Yazdanibakhsh et al., 2019). This study addresses that gap by critically adapting transformative governance theory to Tehran's context. Integrating sustainability transitions, polycentric governance, and social learning frameworks (Pahl-Wostl et al., 2010), it employs qualitative document analysis, expert interviews, and process tracing to identify the institutional and political conditions under which transformative mechanisms may emerge or fail. In doing so, it clarifies both the possibilities and structural limits of governance reform in Tehran and comparable megacities of the Global South.

MATERIALS AND METHODS

This study employs a qualitative exploratory case study design within an interpretive–critical epistemological paradigm to investigate governance dynamics underlying Tehran's air pollution crisis. Given the wicked nature of environmental problems—characterized by complexity, non-linearity, contested values, and contextual embeddedness—methodological approaches must capture meanings, institutional processes, and power relations beyond measurable indicators. Accordingly, this research prioritizes inductive discovery of governance mechanisms and institutional logics over hypothesis testing, pursuing explanatory and theory-building objectives focused on how and why governance arrangements reproduce inertia or enable limited transformation.

The interpretive–critical paradigm enables dual analytical attention: interpreting how actors frame problems and assign responsibility, while critically identifying structural constraints, asymmetrical power relations, and institutional lock-ins. This orientation is particularly suited to authoritarian or hybrid contexts where informal power structures diverge from formal rules, allowing sensitive analysis of interactions between knowledge, power, and practice.

Tehran was purposively selected as a critical, information-rich case due to its persistent pollution crisis, extensive policy interventions, and complex multi-level governance architecture. The city exhibits extreme values in regulatory fragmentation, socio-technical lock-ins, and institutional overlap, enabling analytical generalization to comparable Global South megacities. As a politically centralized yet operationally fragmented system, Tehran serves as a boundary case for identifying minimum conditions under which transformative governance mechanisms might emerge—or remain structurally obstructed.

Document analysis constituted the first data strand, examining governmental and legislative documents from 2010–2024, including environmental laws, Tehran Air Quality Management Plans, inter-agency protocols, emission standards, budgetary reports, parliamentary debates, and regulatory guidelines. A structured coding protocol reconstructed historical governance evolution, identified institutional bottlenecks, and detected patterns of regulatory inconsistency and implementation failure.

Semi-structured interviews formed the primary data source. Twenty-eight participants were selected through purposive and snowball sampling based on institutional diversity, functional

role, and lived governance experience, ensuring representation across governance levels (national, metropolitan, sectoral) and organizational domains (Table 1). The sample emphasized mid-level policymakers and practitioners occupying critical positions for institutional learning and operational decisions. While access to senior political elites was structurally constrained, their influence was examined through document analysis, secondary sources, and interviewee accounts, enabling realistic analysis of power asymmetries. Interviews lasting 60–90 minutes explored: (1) lived experiences of institutional change and coordination; (2) perceived barriers to transformative governance; and (3) proposals for enhancing collective learning and innovation. All interviews were recorded with informed consent and transcribed verbatim.

Interview data were analyzed through iterative open, axial, and selective coding guided by adaptive grounded theory logic. A hybrid analytical strategy combining qualitative content analysis and critical discourse analysis captured both explicit meanings and latent power dynamics embedded in policy narratives. Analytical parameters—governance mechanisms, institutional barriers, learning processes, power asymmetries—were derived through multi-stage integration of theory, document analysis, and interview data. Coding in MAXQDA combined deductive codes from transformative governance theory with inductive codes emerging from empirical material, enabling alignment with constructs including social learning, polycentricity, institutional resilience, and environmental justice (Pahl-Wostl et al., 2010).

Methodological rigor was ensured through triangulation across data sources, member checking, peer debriefing, and reflexive memo-writing. An audit trail documented analytical decisions, enhancing transparency and dependability. Ethical principles—informed consent, anonymity, voluntary participation, data confidentiality—were strictly observed per APA guidelines.

Key limitations include the political sensitivity of environmental governance, restricted participant openness, and limited access to senior political elites. These constraints are analytically consequential, reflecting the power structures under investigation. Despite

Table 1. General Characteristics of Interview Participants by Institutional Affiliation, Organizational Position, Gender, and Environmental Experience

Attribute	Category	Number (n)	Percentage (%)	Description
Institutional Affiliation	Government sector (ministries, municipality, national agencies)	10	35.7	Represents formal and executive governance levels
	Academic and research institutions	6	21.4	Knowledge production and policy analysis
	Civil society organizations and NGOs	7	25.0	Advocacy, public awareness, and social action
	Private sector and media	5	17.9	Links economy, technology, and environmental culture
Organizational Position	Senior managers and policymakers	8	28.6	Decision-making roles at provincial and national levels
	Senior experts and specialists	12	42.9	Technical expertise and field experience
	Faculty members and researchers	5	17.9	Conceptual and analytical framework development
Environmental Experience	Civil activists	3	10.6	Mediation and public discourse
	Less than 10 years	6	21.4	Emerging generation of experts
	10–20 years	15	53.6	Core group of practitioners
	More than 20 years	7	25.0	Highly experienced managers and experts
	Average experience (years)	—	—	14.8
Gender	Male	17	60.7	—
	Female	11	39.3	Significant female representation

limitations, triangulation, reflexivity, and member checking ensured robust analytical credibility.

RESULTS & DISCUSSION

The structural co-occurrence heatmap (Fig. 1), derived from qualitative content analysis of semi-structured interviews ($n = 28$) and policy documents (2010–2024), reveals that Tehran’s air pollution governance is shaped by mutually reinforcing structural barriers rather than discrete administrative inefficiencies. Through iterative deductive–inductive coding and triangulation, four first-order themes were identified: fragmented governance, regulatory path dependency, low public trust, and weak science–policy integration. High-density co-occurrence patterns demonstrate that these barriers operate as reinforcing feedback loops, amplifying rigidity, suppressing adaptation, and reproducing policy inertia.

Air pollution thus persists as a structural property of the governance system. Political, institutional, and epistemic deficits recursively reinforce one another, empirically substantiating theoretical claims that wicked environmental problems are sustained through power–institution–knowledge feedbacks.

Tehran’s air quality governance is institutionally fragmented yet politically centralized. Core actors—including DOE, Ministry of Interior, Tehran Municipality, traffic police, and

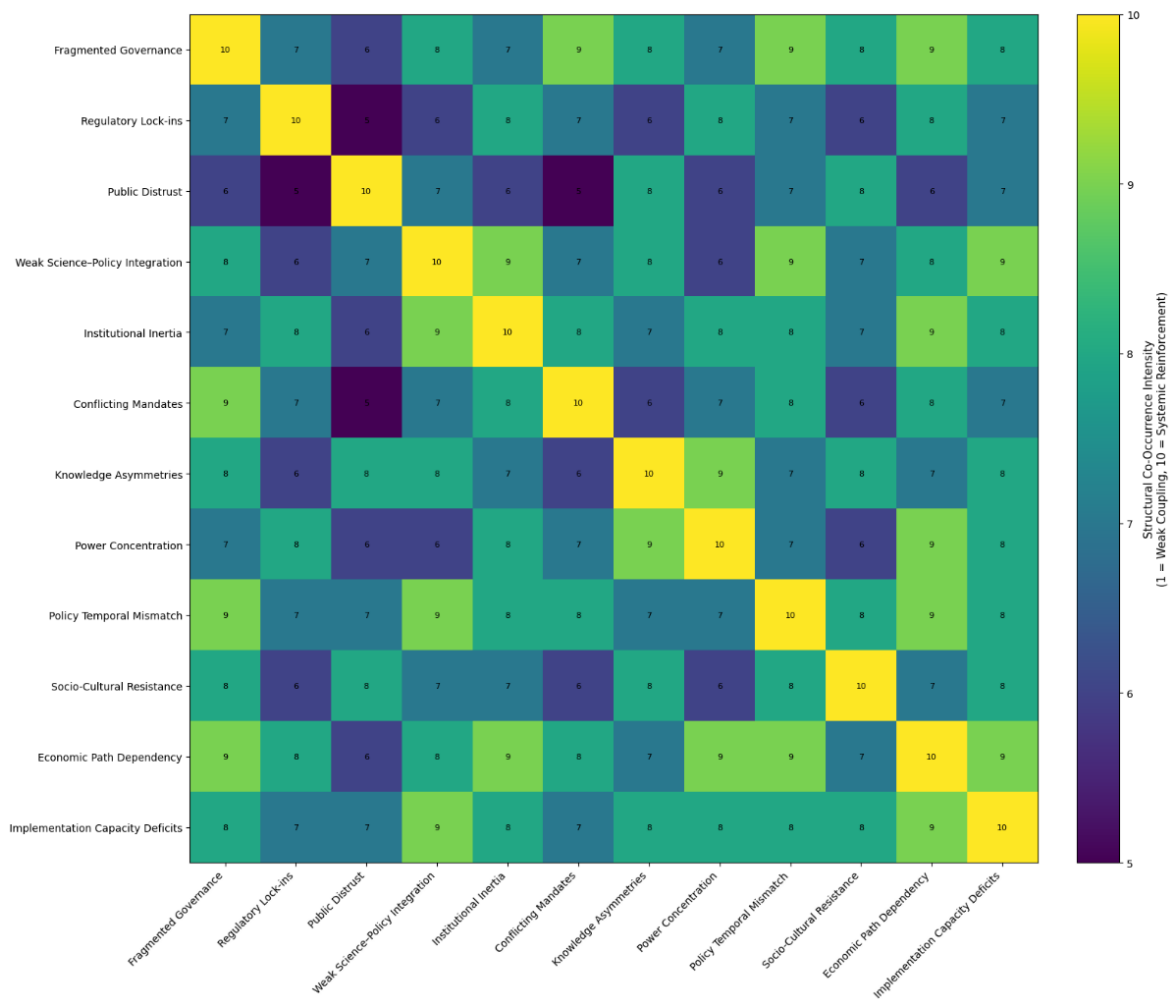


Fig. 1. Heatmap of Co-Occurrence Patterns Among Structural Barriers Identified in Interviews ($N = 28$) and Policy Documents (2010–2024).

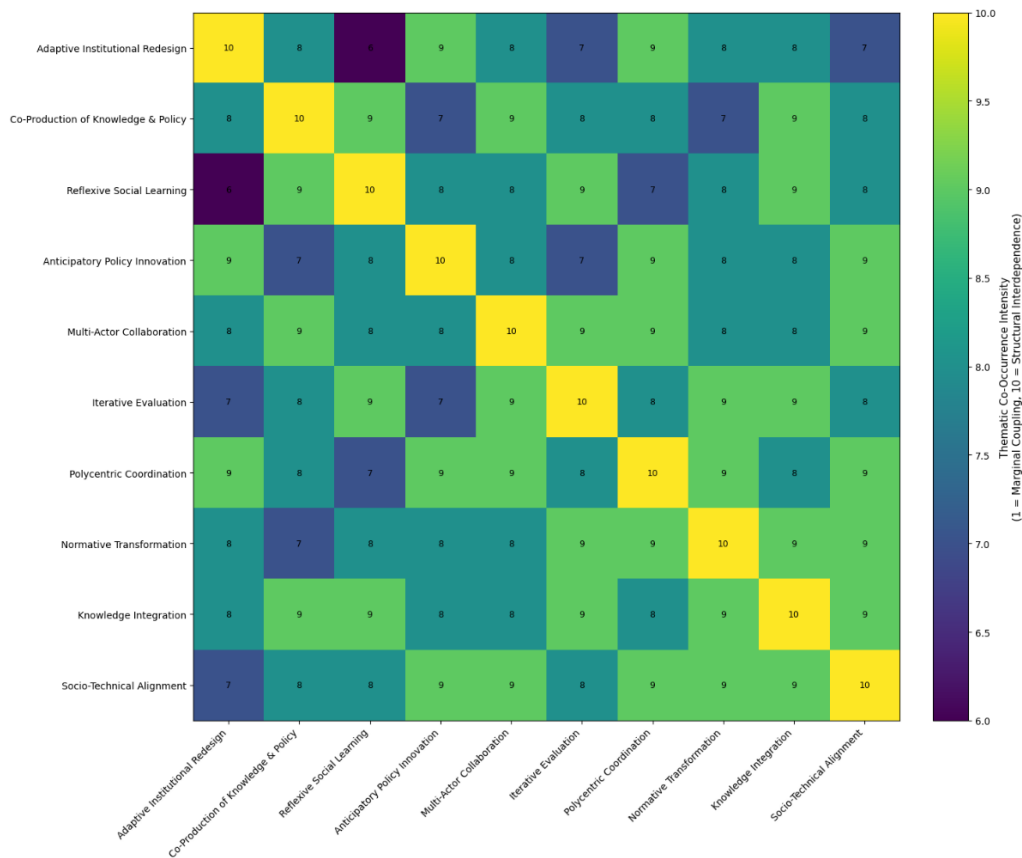


Fig. 2. Heatmap of Thematic Co-Occurrences Across Identified Transformative Governance Mechanisms.

energy bodies—operate in rigid sectoral silos with divergent mandates and performance logics. Fragmentation diffuses responsibility while preserving formal compliance, enabling blame-shifting and delaying decisive action.

The absence of a politically empowered coordinating authority produces symbolic coordination platforms. The Air Pollution Emergency Committee, for instance, is largely reactive and episodic, prioritizing short-term containment (e.g., school closures) over structural drivers such as energy policy and urban form. Without binding authority, coordination becomes ritualized interaction, stabilizing wickedness through institutional paralysis.

Tehran's regulatory framework is deeply shaped by path dependencies embedded in Iran's political economy of energy and industrial protection. Long-standing fuel subsidies institutionalize energy-intensive consumption while rendering reform politically costly. Interviewees emphasized that energy pricing reform faces entrenched resistance.

Automobile-centric planning and protectionist policies further reinforce regulatory lock-in. Emissions standards and fleet renewal programs are selectively enforced, subordinating environmental objectives to industrial and political priorities. These dependencies narrow policy imagination and confine governance to incremental, crisis-driven responses, intensifying systemic vulnerability.

Erosion of public trust constitutes a critical social barrier. Citizens perceive environmental policies as fragmented, inconsistently enforced, and politically instrumentalized, weakening legitimacy and compliance. Demand-side measures therefore generate resentment rather than collective responsibility, particularly when powerful actors remain insulated.

Participatory mechanisms are widely described as procedural rather than empowering. Consultations rarely shape substantive decisions, fostering cynicism and foreclosing co-

production. Participation without influence becomes a structural barrier, undermining legitimacy and adaptive capacity.

Although monitoring data and modeling outputs are abundant, they are weakly embedded in policy cycles. Science is often consulted *ex post* to justify predetermined decisions, reflecting an epistemic governance deficit. Uncertainty is treated as political liability rather than adaptive resource, discouraging experimentation and anticipatory action. The resulting science–policy gap entrenches governance failure and constrains transformation.

Transformative Mechanisms

Fig. 2 illustrates dense co-occurrence among four transformative mechanisms: “adaptive institutional redesign”, “Co-Production of Knowledge and Policy”, “reflexive social learning”, and “anticipatory policy innovation”. These mechanisms co-evolve as an interdependent constellation; effectiveness depends on mutual reinforcement rather than isolated reform.

A. Adaptive Institutional Redesign

Scenario-based network analysis (Fig. 3) shows that governance outcomes depend on

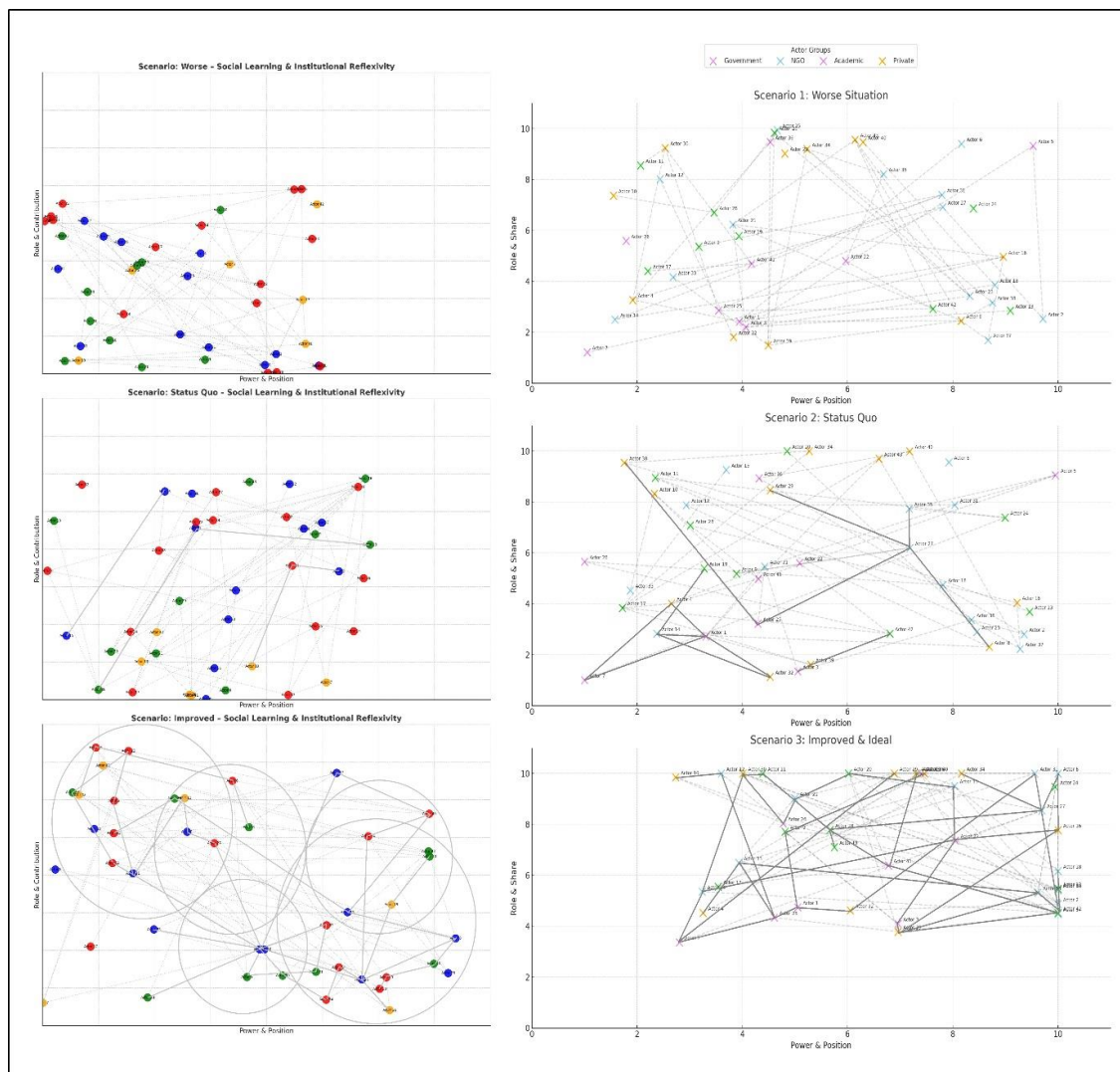


Fig. 3. Comparative scenario-based positioning of key actors in Tehran’s environmental governance system, illustrating variations in social learning capacity and institutional reflexivity across three adaptive institutional redesign scenarios.

relational configuration rather than institutional existence:

- Scenario 1 (Worse): Fragmented, weakly coupled network; nominal governmental authority with low effectiveness; non-state actors peripheral. Hierarchical rigidity exacerbates coordination failures.
- Scenario 2 (Status Quo): Slightly improved connectivity but persistent asymmetrical authority; incremental reforms insufficient.
- Scenario 3 (Improved): Redistributed power, strengthened cross-sectoral ties, formalized coordination hubs; government shifts from controller to orchestrator.

Adaptive redesign implies conditional re-regulation—embedding flexibility within binding coordination architectures. Coordination endowed with enforcement authority becomes transformative.

B. Co-Production of Knowledge and Policy

Co-production addresses epistemic asymmetry between technocratic expertise and lived experience. Integrating scientific data with local and experiential knowledge enhances contextual fit and legitimacy. Institutionalized participatory platforms—citizen sensing, neighborhood forums, collaborative scenario-building—redistribute epistemic authority and embed social learning in governance routines.

Co-production functions politically by reshaping authority relations and fostering shared ownership, positioning it as a structural pillar of transformation rather than consultative add-on.

C. Reflexive Social Learning

Learning capacity fundamentally shapes adaptability.

- **Worse scenario:** Compliance-oriented, failure concealed.
- **Status Quo:** Selective, informal learning; limited transformation.
- **Improved:** Institutionalized feedback loops, mandatory reviews, transparent reporting.

Reflexive learning enhances resilience by normalizing experimentation and adaptive correction, amplifying other transformative mechanisms.

D. Anticipatory Policy Innovation

Reactive crisis management dominates current practice. Anticipatory innovation—foresight, scenario planning, pilot experimentation—extends temporal horizons and governs through uncertainty. Domains include electrified transport, low-emission zones, and clean energy transitions. Innovation is cyclical and learning-oriented, enhancing institutional readiness under deep uncertainty.

Political Feasibility and Power Constraints

Transformative mechanisms operate within entrenched political–economic lock-ins. Energy subsidies and industrial protectionism serve regime stability, rendering reform politically sensitive. Adaptive redesign, co-production, and reflexive learning challenge centralized authority and are vulnerable to symbolic adoption.

Anticipatory innovation is rhetorically endorsed but often weakly institutionalized due to short political time horizons. Transformation thus advances incrementally through selective entry points and windows of opportunity. Governance reform is politically contingent rather than technocratically linear.

System-Level Dynamics

Cross-analysis (Fig. 4) confirms strong systemic coupling among transformative mechanisms. Anticipatory innovation requires reflexive learning; redesign without co-production risks technocratic rigidity; isolated reforms are absorbed into existing power structures.

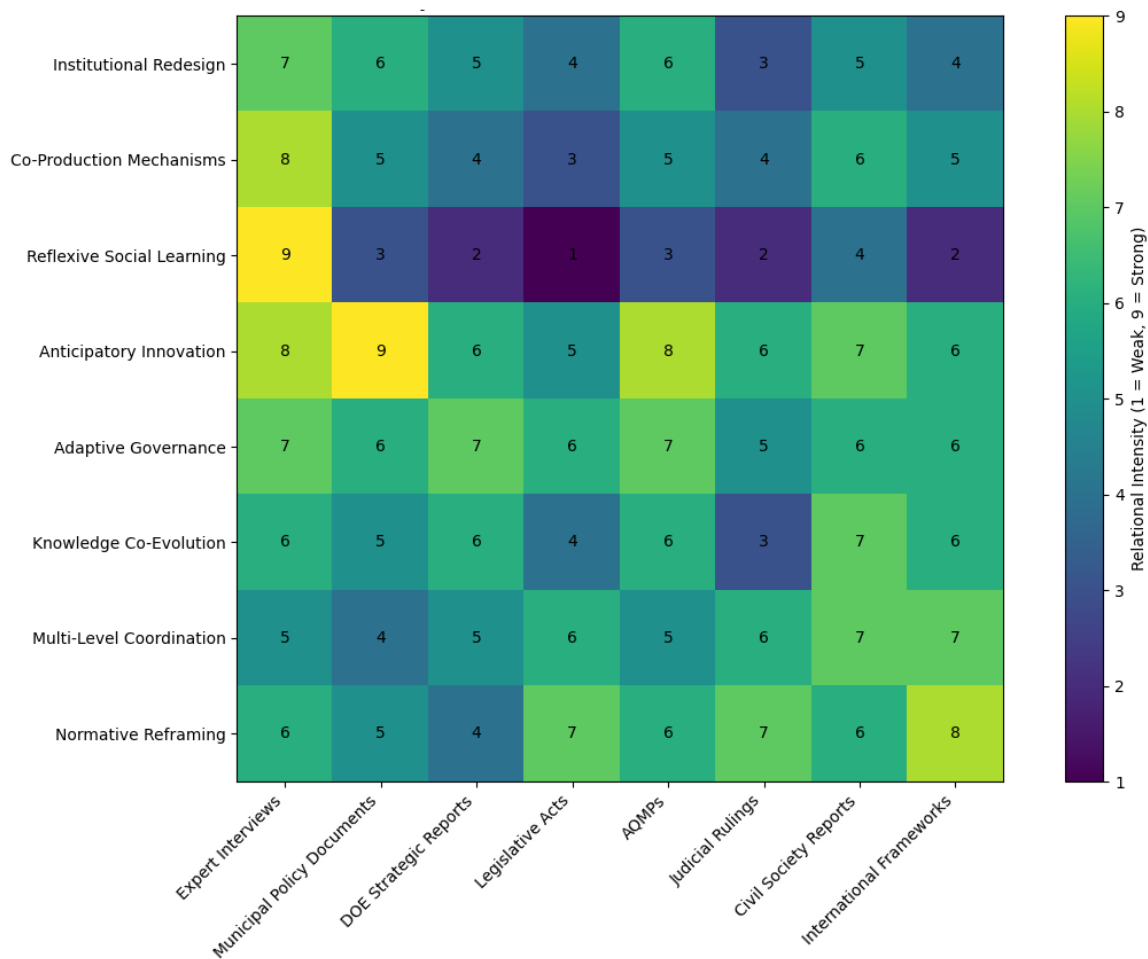


Fig. 4. Source–Mechanism Heatmap Showing Alignment Between Interview Data and Policy Documents.

Heatmap patterns reveal discourse–practice gaps: learning emphasized in interviews but weakly institutionalized; innovation rhetorically present yet lacking binding evaluation. Power asymmetries determine which mechanisms advance. Transformative governance is therefore a co-evolving ecosystem shaped by political economy and institutional hierarchy.

Emergent Conditions for Transformation

Effective transformation requires alignment of:

1. Institutional Authority – Binding legal mandates for cross-sectoral coordination stabilize reform trajectories.
2. Social Legitimacy – Trust and participatory engagement foster compliance and shared ownership.
3. Epistemic Capacity – Integration of monitoring, modeling, and foresight into iterative cycles enhances adaptive governance.

Crises create momentum but yield durable change only when embedded within anticipatory and reflexive architectures.

Conceptual Model

The proposed Transformative Multi-Scale Environmental Governance Model (Fig. 5) integrates a six-phase iterative cycle—vision setting, co-designed policy formulation,

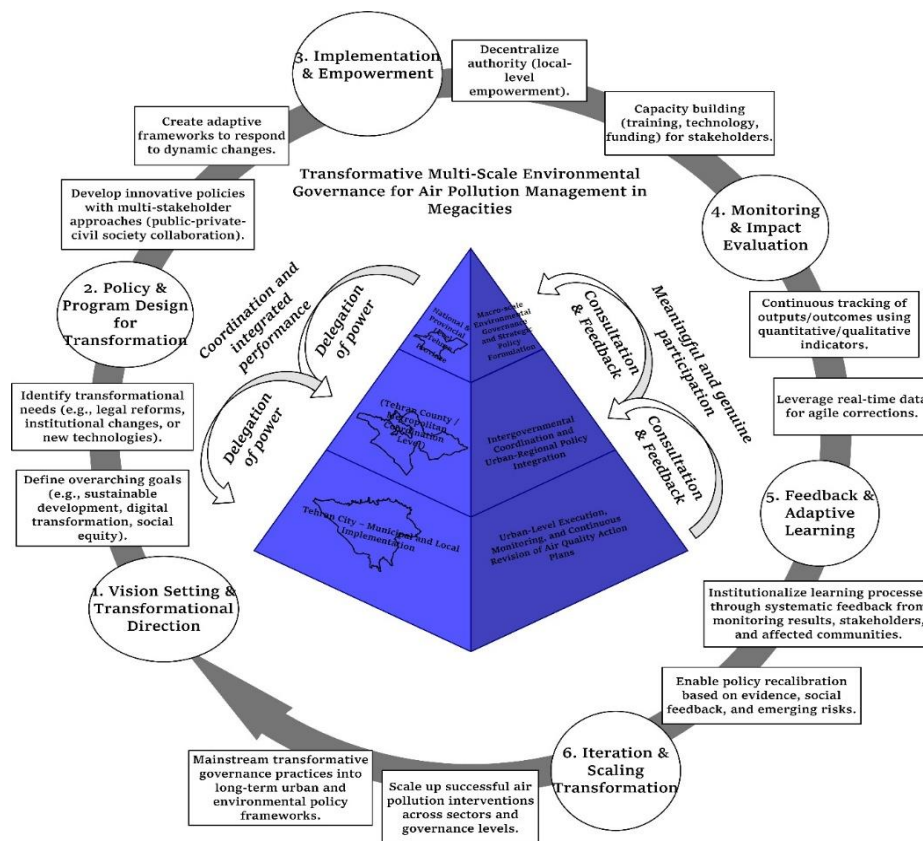


Fig. 5. An integrative conceptual model of Transformative Multi-Scale Environmental Governance for Air Pollution Management in Megacities

empowerment-oriented implementation, monitoring, adaptive learning, and scaling—with a multi-level governance pyramid (macro, meso, metropolitan, micro). Authority delegation and feedback flows are explicitly conditioned by political feasibility.

The model advances environmental governance scholarship by:

1. Integrating adaptive redesign, co-production, reflexive learning, and anticipatory innovation systemically;
2. Embedding power dynamics and multi-level coordination;
3. Emphasizing iteration, learning, and political navigation under wicked uncertainty.

Comparative and Theoretical Synthesis

Tehran's case aligns with scholarship emphasizing limits of technical solutions (Pahl-Wostl, 2009; Yazdanibakhsh et al., 2019). Transformative governance reframes wicked problems through collaborative meta-governance (Rittel & Webber, 1973; Head, 2023), enhancing legitimacy and adaptability (Lemos & Agrawal, 2006; Meadowcroft, 2013).

Comparative cases illustrate political conditioning of feasibility: Mexico City's gradual empowerment and civic pressure (West et al., 2004; Molina et al., 2019; Silva Rodríguez de San Miguel, 2019); Cairo's bureaucratic fragmentation (Ghanem et al., 2023); Beijing's authoritarian environmentalism (Li et al., 2019; Wang & Chen, 2024); Moscow's centralized constraints (Aleksandrovich et al., 2016; Elansky et al., 2018; Van der Heijden et al., 2020). Institutional redesign and experimentation align with adaptive governance theory (Evans et al., 2016). Social learning and co-production enhance resilience (Pahl-Wostl et al., 2010). Anticipatory capacity strengthens adaptive systems (Biggs et al., 2015; Folke et al., 2016). However, centralized

political structures constrain implementation. Transformative mechanisms require power redistribution; thus reform depends on strategic coalition-building and opportunity windows (Jordan et al., 2018; Yousefian et al., 2025).

CONCLUSION

This study provides robust empirical and theoretical evidence that transformative governance constitutes a practicable framework for addressing wicked environmental challenges, exemplified by Tehran's persistent air pollution. Unlike linear policy approaches, transformative governance emphasizes adaptive, anticipatory, and learning-oriented mechanisms that enable systemic change within complex, path-dependent socio-technical and institutional configurations. By operationalizing social learning, institutional flexibility, and forward-looking policy design, governance actors can move beyond short-term technical fixes toward structurally embedded and sustainable interventions.

Empirical findings highlight the pivotal role of polycentric governance and multi-level coordination in overcoming regulatory fragmentation, sectoral silos, and institutional inertia. Such configurations enable collective problem reframing, iterative experimentation, and reflexive decision-making—processes essential for addressing the enduring wickedness of urban air pollution. In Tehran, these dynamics could materialize through pilot low-emission initiatives, citizen-based monitoring systems, and anticipatory urban planning strategies that simultaneously strengthen legitimacy, effectiveness, and adaptive capacity. The findings reaffirm that technological interventions alone are insufficient; sustainable environmental reform requires alignment between technical measures and relational–cognitive governance processes.

Theoretically, the study advances international scholarship by demonstrating how adaptive capacity emerges from the dynamic interplay of institutional redesign, social learning, and anticipatory foresight. By bridging abstract governance theory with operational mechanisms in a megacity context, the research extends the analytical boundaries of urban environmental governance. It further underscores that sustainable governance depends on integrating forward-looking strategies with reflexive learning, ensuring policy adaptability amid socio-ecological uncertainty and political volatility.

From a policy perspective, the study offers concrete reform pathways: institutionalizing reflexive social learning, promoting knowledge co-production among state and non-state actors, and embedding anticipatory, transition-oriented policies within coherent governance architectures. Iterative experimentation and adaptive feedback loops can enhance institutional legitimacy, societal buy-in, and long-term environmental resilience. Reframing episodic crises as opportunities for systemic reform is therefore essential to converting environmental emergencies into catalysts for transformative change.

Notwithstanding these contributions, limitations remain. The qualitative design may constrain cross-contextual generalizability, while Tehran's volatile political landscape complicates reform implementation. Moreover, the long-term effectiveness of transformative governance depends on sustained political commitment, cross-sectoral coordination, and institutional stability. Future research should incorporate quantitative modeling, comparative cross-city analysis, and longitudinal evaluation to strengthen the explanatory and predictive capacity of transformative governance frameworks.

Ultimately, the study affirms that enduring urban environmental challenges demand a paradigmatic shift from technocratic solutions toward adaptive, collaborative, and anticipatory governance. Environmental transformation is fundamentally socio-political as well as technical, requiring integrative approaches that align institutions, knowledge systems, and societal actors toward resilient and future-oriented governance pathways.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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