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ALGORITHMIC URBANISM AND STRUCTURAL INEQUALITY: A CRITICAL ASSESSMENT OF ARTIFICIAL INTELLIGENCE IN URBAN SYSTEMS

Artificial intelligence is increasingly deployed to optimise urban energy systems, transport networks, and housing markets. However, its infrastructure frequently reproduces structural inequalities, imposing environmental and social costs onto marginalised communities whilst concentrating benefits among capital-holding actors. This paper argues hypothesis that AI urbanism, as currently embedded within existing urban political economies, functions as a mechanism of cost externalisation rather than public service optimisation: efficiency gains accrue to capital-holding actors whilst costs are displaced onto marginalised communities and peripheral territories. This study adopts a qualitative, critical analytical approach, combining a systematic literature synthesis with comparative case studies across three urban domains of energy, transport, and housing, drawing on evidence from both the Global North and the Global South. The informational basis combines peer-reviewed scholarship, intergovernmental reports, and investigative journalism. The study relies on secondary sources, which constitutes its principal limitation alongside the

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АЛГОРИТМІЧНИЙ УРБАНІЗМ ТА СТРУКТУРНА НЕРІВНІСТЬ

Штучний інтелект (ШІ) дедалі активніше впроваджується в міські системи, зокрема в енергетичні мережі, транспортну інфраструктуру та ринок житла. Проте його інфраструктура часто відтворює структурну нерівність, оскільки екологічні та соціальні витрати непропорційно покладаються на маргіналізовані громади, тоді як вигоди концентруються серед тих, хто має капітал та інфраструктурну владу. Висунуто гіпотезу, що ШІ-урбанізм, вбудований у міські політичні економії, функціонує як механізм екстерналізації витрат, а не як оптимізація публічних послуг. Алгоритмічні системи в цьому контексті сприяють концентрації ефективності, ресурсів і прибутків серед капіталомістких акторів, тоді як екологічні та соціальні ризики непропорційно покладаються на маргіналізовані групи населення. Застосовано якісний критично-аналітичний підхід, поєднуючи систематичний синтез літератури з порівняльними кейсами у трьох доменах: енергетиці, транспорті та житловому секторі, з доказами як з країн Глобальної Півночі, так і з країн Глобального Півдня. Інформаційну базу становлять рецензовані наукові праці, міжурядові доповіді та матеріали журналістських розслідувань. Результати аналізу *rapidly evolving nature of AI governance. The analysis revealed that AI data centre infrastructure in Mesa, Arizona, extracted 5.5 million cubic metres of water annually whilst residential construction permits were simultaneously revoked due to aquifer depletion. In Caucaia, Brazil, a proposed data centre would consume electricity equivalent to 2.2 million households, exemplifying computational colonialism in peripheral economies. In transport, the Waze for Cities programme in Joinville, Brazil, created extractive data dependency that undermined municipal governance capacity, whilst Singapore's publicly governed system demonstrated that equitable outcomes are achievable under different governance architectures. In housing, Barcelona's Sant Marti district experienced algorithmic amplification of gentrification, displacing low-income residents despite environmental improvements. The paradox of AI urbanism is sustained not by technical failure but by the political economy in which these systems operate. The study provides recommendations for municipal authorities to implement public data trusts, participatory governance mechanisms, and wellbeing-oriented optimisation metrics, ensuring that AI-driven urban systems serve collective wellbeing over capital accumulation.*

Keywords: AI urbanism, urban sustainability, algorithmic inequality, computational colonialism, data sovereignty, political economy.

показали, що інфраструктура центрів обробки даних у м. Месі (штат Арізона) споживала щорічно 5.5 млн м^3 води, тоді як дозволи на нове житлове будівництво одночасно скасовувалися через виснаження водоносних горизонтів. У Каукаїї (Бразилія) запронований центр обробки даних споживав би електроенергію, еквівалентну потребам 2.2 млн домогосподарств. У сфері транспорту програма Waze for Cities у Жуанвілі (Бразилія) створила залежність від приватної платформи, що підривала муніципальний суверенітет даних, тоді як публічно керована система Сингапуру продемонструвала досяжність справедливих результатів за інших умов управління. У сфері житла район Сант-Марті у Барселоні зазнав алгоритмічного посилення джентрифікації, що призвело до витіснення малозабезпечених мешканців попри екологічні покращення. Встановлено, що парадокс ШІ-урбанізму зумовлений не технічними збоями, а політичною економією, в якій функціонують ці системи. Сформовано рекомендації для муніципальних органів влади щодо впровадження публічних довірчих фондів даних, механізмів партиципативного управління та метрик оптимізації, орієнтованих на добробут, з метою забезпечити функціонування міських систем на основі ШІ в інтересах добробуту, а не для накопичення капіталу.

Ключові слова: ШІ-урбанізм, міська сталість, алгоритмічна нерівність, обчислювальний колоніалізм, суверенітет даних, політична економія.

JEL Classification: R10, R58, O33, L86, Q50.

Introduction

Algorithmic systems have become foundational instruments for governing urban infrastructure, enabling cities to coordinate energy consumption, regulate traffic flows, and administer housing allocation at unprecedented scales. Yet the widespread enthusiasm for AI's problem-solving capacity coexists with a structural paradox: the very systems designed to optimise urban life frequently reinforce the material and political inequalities they claim to address. The proposed data centre in Caucaia, Brazil, illustrates this tension concretely: community protests exposed how the facility's environmental burdens on a water-stressed region were systematically disregarded, revealing how optimisation logics operate in ways that override local ecological and social thresholds (Martins & Amorim, 2025).

The hypothesis underlying this study is that AI urbanism, as embedded within existing urban political economies, functions as a mechanism of cost externalisation rather than public service optimisation: efficiency gains are systematically captured by capital-holding actors whilst environmental, governance, and social costs are displaced onto marginalised communities and peripheral territories. This analysis builds upon and expands the theoretical framework initially proposed in the author's preliminary study on algorithmic systems in urban contexts (Tonon, 2025). The hypothesis is tested through a critical synthesis of urban studies, political ecology, and technology governance literature, structured around comparative case studies across three domains, with cases drawn from both the Global North and the Global South.

Within urban contexts, AI urbanism describes the growing influence of algorithmic systems on spatial planning, infrastructure management, resource distribution, and governance structures (Cugurullo et al., 2024). Central to this paradigm is optimisation: a logic that seeks to improve outcomes through data-driven prediction and control. Yet aligning AI with the Sustainable Development Goals remains structurally ambiguous. Whilst AI can facilitate the achievement of 134, or 79%, of SDG targets across several dimensions, it simultaneously risks hindering 59, or 35%, of targets across social, economic, and environmental dimensions (Vinuesa et al., 2020). These tensions confirm that optimisation is never a neutral technical operation, but one shaped by the political economies and governance architectures in which AI systems are embedded (Vinuesa et al., 2020; Cugurullo et al., 2024).

This study adopts a qualitative, critical analytical approach, combining a systematic literature synthesis with comparative case analysis across three urban domains. Cases were selected from both the Global North and the Global South, following a logic of maximum variation to assess whether identified patterns are geographically contingent or structurally determined. The reliance on secondary sources constitutes the study's principal methodological limitation; however, this is consistent with its theoretical objectives, which seek to identify structural patterns rather than generate primary empirical data. The analysis builds upon the preliminary framework developed in Tonon (2025) and extends it through an explicit economic dimension.

The article is structured as follows. Section 1 surveys the measurable advances in urban sustainability that AI enables across energy, transport, and housing, establishing that the critique targets AI's current political-economic embedding rather than its technical potential. Section 2 examines material contradictions and structural inequalities produced across the same three domains through paired case studies from the Global North and Global South. Section 3 analyses the economic mechanisms that explain why these patterns persist. Section 4 considers the institutional conditions necessary for more equitable AI governance. The conclusions synthesise the findings and position the study's contribution to the critical AI urbanism literature.

1. Advances in sustainability

Proponents of AI urbanism argue that algorithmic optimisation delivers measurable improvements in resource efficiency, pollution reduction, and infrastructure management across energy, transport, and housing sectors (OECD, 2019). This section examines three domains where AI evidently advances sustainability metrics, whilst maintaining critical awareness that efficiency gains do not automatically translate into equitable or ecologically sustainable outcomes.

1.1. Energy: smart grids and renewable integration

AI-driven smart grids revolutionise urban energy systems by dynamically balancing supply and demand, integrating variable renewable sources, and reducing overall consumption. Machine learning algorithms predict consumption patterns and coordinate renewable energy sources, utilising satellite imagery to create emissions predictions essential for power system optimisation and disaster management (UN-Habitat, 2022). This capacity is particularly valuable in smart cities, where energy consumption fluctuates with weather conditions, time of day, and population density. Barcelona exemplifies this implementation, applying AI-powered solutions in smart lighting and waste management to measurably reduce energy consumption and carbon footprints (Singh & Shah, 2024).

1.2. Transport: route optimisation and emission reduction

Algorithmic transport optimisation targets congestion reduction, emission minimisation, and mobility efficiency through interconnected systems aligned with SDGs 11.2, 11.3, and 11.6 (UN-Habitat, 2022). AI systems manage traffic flow by analysing real-time sensor and camera data, enabling dynamic signal adjustments and vehicle rerouting that significantly reduce congestion (UN-Habitat, 2022). Singapore's traffic management system demonstrates this potential at scale, substantially reducing congestion and travel times whilst anticipating potential incidents (Singh & Shah, 2024). This case is instructive precisely because, as Section 2 will show, such outcomes depend fundamentally on governance architecture rather than technology alone.

1.3. Housing: building management and resource efficiency

Smart building technologies apply AI to optimise energy, water, and occupant comfort simultaneously, addressing SDGs 11, 9, 12, 7, and 3 (UN-Habitat, 2022). Integrated with IoT sensors, these systems enable continuous monitoring, proactive maintenance, and automated temperature control (Singh & Shah, 2024). Mehdi (2018) documents 25 to 35% reductions in energy consumption through such automated systems.

These applications demonstrate AI's technical capacity for measurable efficiency improvements. The following section examines the critical questions they raise: efficiency for whom, at what hidden costs, and through what governance structures?

2. Material contradictions and structural inequalities

The material infrastructure sustaining AI-driven urbanism, comprising data centres, computational networks, and digital platforms, places enormous demands on water and energy systems already under pressure from climate change (Lee, 2025). These burdens fall disproportionately on vulnerable communities across the Global North and South (Sharma et al., 2023). Rather than redistributing resources equitably, AI systems operationalise a logic of capital accumulation, embedding patterns of extraction characteristic of colonial resource regimes within the governance structures of ostensibly progressive smart cities (Cugurullo, 2021). The following case studies demonstrate how this logic generates economic asymmetry across energy, transport, and housing, producing systematic cost externalisation onto marginalised populations whilst concentrating benefits among technology corporations and high-income urban residents (Sharma et al., 2023).

2.1. Energy: water extraction and computational colonialism

AI-driven energy optimisation masks significant material contradictions: computational infrastructure consumes water at scales that threaten community access in water-stressed regions (Barratt et al., 2025). Data centres are frequently sited in arid regions to minimise corrosion, paradoxically concentrating consumption precisely where water is scarcest. One study projects AI-driven facilities could consume up to 1.7 trillion gallons globally by 2027 (Fleury & Jimenez, 2025).

Mesa, Arizona. In Mesa, Arizona, a region experiencing extreme drought, authorities permitted Google's data centre to extract 5.5 million cubic metres of water annually, equivalent to the annual consumption of 23,000 residents. This occurred whilst residential construction permits were revoked due to aquifer depletion. The decision reveals a political-economic hierarchy in which corporate infrastructure investment takes precedence over community need: the same resource whose scarcity was being used to deny housing permits was simultaneously being allocated to a private data centre. Recent investigations identified 632 existing data centres, including 38 already located in water-stressed areas and another 24 under development, collectively representing a 78% increase in planned capacity, placing Mesa within a systematic pattern (Barratt et al., 2025).

Caucaia, Brazil. The proposed TikTok data centre in Caucaia, Brazil, exemplifies computational colonialism: resource extraction from peripheral regions sustaining centralised digital infrastructure (Cugurullo, 2021).

The facility would consume electricity equivalent to 2.2 million homes, exceeding 99.9% of Brazilian municipalities' per-capita use, and would rank as Brazil's seventh-largest electricity consumer as a single entity (Martins & Amorim, 2025). The asymmetry is stark: the data centre would generate digital value for global platforms whilst imposing energy and water burdens on a water-stressed region with limited capacity for legal or political contestation. Community protests against the facility reveal that the affected population recognised this asymmetry clearly, even when regulatory frameworks did not (Martins & Amorim, 2025).

Together, Mesa and Caucaia reveal that the logic of externalisation operates consistently across distinct regulatory and geographic contexts: costs are imposed on communities selected precisely because their capacity to resist is weakest. This is a structural feature of how AI infrastructure is deployed, not an incidental failure (Cugurullo, 2021; Sharma et al., 2023).

2.2. Transport: data extraction and municipal sovereignty

The political economy of AI transport optimisation is characterised by structural economic asymmetry: platform corporations extract commercially valuable municipal datasets whilst providing minimal reciprocal benefit, systematically diminishing local governance capacity and concentrating analytical power within private technology corporations (UN-Habitat, 2022). Smart mobility systems thus function less as instruments of public service than as mechanisms of data extraction and capital accumulation. Through network effects and proprietary data architectures, platform corporations position themselves as indispensable intermediaries, generating a form of cost externalisation whereby the public investment required to produce valuable urban data is borne by municipalities, whilst the economic returns accrue entirely to private platforms (Hiroki, 2021; Sharma et al., 2023; UN-Habitat, 2023).

Singapore. Singapore's AI-assisted traffic management demonstrates what is technically achievable when algorithmic systems are deployed within strong public governance frameworks. The city-state retains public ownership of its transport data infrastructure, enabling AI optimisation to serve collective mobility goals rather than platform profit. The result is a system that genuinely reduces congestion and travel times whilst maintaining public accountability, instructive as evidence that AI outcomes depend fundamentally on governance architecture: who owns the data, who sets the targets, and to whom the system is accountable (Singh & Shah, 2024).

Joinville, Brazil. The contrast with Joinville, Santa Catarina, is instructive. The city's participation in the Waze for Cities programme created a dependency in which the platform retained software ownership and patents whilst providing only filtered, partial information insufficient for medium- or large-scale traffic planning (Hiroki, 2021). Although municipal officials recognised the imbalance, Waze's market dominance left few alternatives.

This dynamic reproduces colonial extraction patterns: data flows from the periphery to the core, whilst analytical capacity concentrates in Global North corporate headquarters, weakening municipal data sovereignty and limiting autonomous policymaking aligned with community needs (Hiroki, 2021; Sharma et al., 2023). This vulnerability is particularly acute in Global South cities, where limited budgets and expertise create greater exposure to exploitative data arrangements (Hiroki, 2021; Sharma et al., 2023).

Singapore and Joinville demonstrate that the AI paradox in transport is not technical but political: the same algorithmic tools produce radically different outcomes depending on who controls the data and what governance frameworks protect public interests.

2.3. Housing: algorithmic discrimination and access barriers

AI housing systems reproduce and amplify existing discrimination, creating algorithmic barriers that restrict access for marginalised communities whilst optimising markets for investor profit rather than residential need (Rosen & Garboden, 2024; Sharma et al., 2023). Research on the US housing market demonstrates that AI-driven systems reproduce racial discrimination, systematically restricting access for racialised minorities in ways that mirror historical patterns of exclusion (Rosen & Garboden, 2024). Machine learning models treat discrimination as a signal rather than a bias to be corrected, thereby reinforcing racist market structures (Cugurullo & Xu, 2025). Algorithmic opacity obscures these dynamics, limiting accountability and enabling corporations to maintain plausible deniability (Cugurullo & Xu, 2025; Lee, 2025; Sharma et al., 2023).

Barcelona. Barcelona’s Sant Marti district illustrates how environmental improvements, mediated by algorithmic housing systems, can accelerate displacement of the very communities they were ostensibly designed to benefit. Between 1992 and 2006, the creation of 18 parks attracted higher-income residents: adults with university degrees rose by 27.92% and household income by 26.7%, far above district-wide trends (Anguelovski et al., 2018). Market algorithms classified the area as a high-return zone whilst labelling vulnerable residents as high risk, channelling investment and driving up costs. Low-income populations were consequently displaced to Nou Barris, where algorithmic systems continued to rate the neighbourhood negatively despite the presence of green amenities, reinforcing structural inequalities (Anguelovski et al., 2018; Sharma et al., 2023; UN-Habitat, 2022).

Sant Marti reveals a deeper contradiction: AI does not cause gentrification but amplifies and accelerates it, identifying investment opportunities whilst simultaneously flagging existing residents as financial risks (Othengrafen et al., 2025). This transforms environmental improvement into a mechanism of displacement, making the process harder to contest and easier to conceal behind ostensibly neutral data-driven decision-making.

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These contradictions reveal AI urbanism's fundamental tension with genuine sustainability (Cugurullo, 2021; Sharma et al., 2023): energy systems extract water from drought-stressed communities, transport platforms extract data from municipalities, and housing algorithms extract access from marginalised residents, all whilst claiming optimisation. What unites these three domains is a shared economic logic: the externalisation of costs onto those least able to contest them, and the internalisation of gains by those who control infrastructure and capital. The following section examines the mechanisms through which this logic is reproduced.

3. Economic dimension: the political economy of AI urbanism

The contradictions documented across the three domains are not incidental outcomes of imperfect implementation. They reflect the political economy within which AI urbanism operates: a structure that systematically generates economic efficiency for those who hold capital and infrastructure power, whilst producing systematic cost externalisation onto communities and municipalities that do not. Three interconnected mechanisms of economic asymmetry sustain this pattern (Cugurullo, 2021; Sharma et al., 2023).

First, the concentration of AI infrastructure investment among a small number of global platform corporations enables these actors to extract favourable terms from host governments, including tax incentives, subsidised energy tariffs, and loosened environmental permitting (IEA, 2024). Corporations thus capture the economic value of urban data and AI services whilst externalising infrastructure costs such as water depletion onto local communities and public budgets. Mesa and Caucaia exemplify this: in both cases, scarce public resources were allocated to private digital infrastructure through governance frameworks that prioritised corporate investment over community need (Barratt et al., 2025; Martins and Amorim, 2025).

Second, the commodification of urban data creates persistent asymmetries between platform corporations and municipalities. As the Joinville case illustrates, proprietary platforms extract commercially valuable datasets from public infrastructure investment, monetising traffic patterns, mobility behaviour, and spatial demand signals through advertising and logistics optimisation, whilst municipalities receive only partial, filtered information in return (Hiroki, 2021). This redistribution of urban surplus from public institutions towards technology corporations weakens the fiscal and institutional base from which municipalities might otherwise develop autonomous, equity-oriented policies.

Third, in housing markets, AI amplifies existing capital advantages by enabling institutional investors to act on investment signals at a speed and scale unavailable to individual households or municipal governments (Othengrafen et al., 2025). Barcelona demonstrates this amplification: algorithmic systems did not introduce gentrification to Sant Marti, but accelerated and deepened it in ways that manual market analysis could not match. These three mechanisms interact and reinforce one another, which is why piecemeal technical reforms consistently produce limited results: the AI paradox is sustained not by flawed algorithms, but by the political economy in which they operate (Cugurullo, 2021; Sharma et al., 2023).

4. Conditions of possibility

If the paradox of AI urbanism is structural rather than incidental, as the preceding analysis demonstrates, then addressing it requires structural responses: not better algorithms, but different ownership arrangements, different governance architectures, and different definitions of what optimisation is for. Three transformations emerge as essential: public data sovereignty (UN-Habitat, 2022), democratic participation in design processes (Othengrafen et al., 2025), and optimisation metrics prioritising justice alongside efficiency (Sharma et al., 2023). These are not independent recommendations but interconnected conditions, and none is sufficient without the others.

4.1. Public data sovereignty and municipal ownership

Municipal and cooperative data ownership enables alternative outcomes prioritising equity alongside efficiency. Barcelona’s Decidim platform demonstrates this possibility: a free, open data commons infrastructure for participatory democracy that achieves high implementation rates for citizen proposals (Bernardi, 2019). However, Caucaia’s resistance against data centre infrastructure reveals that public ownership alone proves insufficient without robust accountability mechanisms and capacity to contest corporate power (Martins & Amorim, 2025). Data sovereignty must combine legal ownership with institutional capacity-building and community technical expertise, as the contrast between Decidim and the Joinville arrangement illustrates: the difference is not technical but political (Bernardi, 2019; Hiroki, 2021; UN-Habitat, 2022).

4.2. Participatory governance

Democratic participation in AI system design challenges technocratic decision-making that excludes affected communities. Effective participation requires more than consultation; it demands redistributing decision-making power over algorithmic systems, including community oversight of data practices, transparent audits, and mechanisms to contest automated decisions (Sharma et al., 2023; UN-Habitat, 2022). The resistance to Caucaia’s proposed data centre demonstrates how organised communities can oppose corporate infrastructure even when regulatory frameworks fail them, though their capacity to participate remains limited when state decisions override local mobilisation (Martins & Amorim, 2025). Genuine participatory governance therefore requires legal frameworks protecting community veto

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power, binding consultation requirements, and resources for communities to develop the technical capacity necessary for meaningful engagement (Cugurullo, 2021).

4.3. Alternative metrics

Reconceptualising optimisation metrics challenges the growth-oriented logic embedded in AI urbanism. Doughnut Economics offers an alternative framework prioritising ecological sustainability and social equity over GDP expansion (Raworth, 2017; DEAL, 2024). More than 70 cities worldwide are exploring adoption through DEAL's Data Portrait of Place, a tool generating holistic assessments of local social and ecological performance (DEAL, 2024). By establishing legitimate wellbeing metrics, the framework helps municipalities resist profit-maximising optimisation logics (Raworth, 2017). Yet implementation faces major barriers: the computational colonialism documented in Caucaia shows the consequences of leaving profit-driven optimisation unchallenged, whilst Barcelona's green goods polarisation demonstrates how environmental improvements produce inequitable outcomes when distributional concerns are sidelined (Anguelovski et al., 2018; Martins & Amorim, 2025). Alternative metrics must therefore be paired with governance reforms ensuring algorithmic systems advance collective welfare, constrained as they are by corporate resistance and structural power asymmetries favouring capital over communities (Sharma et al., 2023).

Conclusions

AI generates measurable gains in renewable integration (Vinuesa et al., 2020), mobility optimisation (Singh & Shah, 2024), and building performance (UN-Habitat, 2022). Yet its infrastructures frequently externalise socioecological harms, from water extraction in drought-stressed regions (Barratt et al., 2025) to the erosion of municipal data sovereignty (Hiroki, 2021) and discriminatory housing outcomes (Anguelovski et al., 2018; Rosen & Garboden, 2024). Its impact, therefore, turns not on technical capacity but on governance structures shaped by corporate control and uneven resource flows, which reproduce forms of computational colonialism (Cugurullo, 2021; Sharma et al., 2023).

The case studies demonstrate that these patterns are not geographically confined or sectorally specific. In energy, Mesa and Caucaia reveal how infrastructure costs are imposed on communities selected for their limited capacity to resist. In transport, Singapore and Joinville show that the same tools produce radically different outcomes depending on who owns the data. In housing, Barcelona's Sant Marti illustrates how AI transforms environmental improvement into a mechanism of displacement.

These patterns persist because they are sustained by a political economy that concentrates AI's benefits among capital-holding actors whilst externalising its costs. Achieving genuine sustainability, therefore, requires moving beyond tech-centric approaches towards transforming ownership structures, governance models, and optimisation logics themselves (Cugurullo, 2021; Sharma et al., 2023). Public ownership of data infrastructures, participatory institutions with enforceable community rights, and optimisation metrics aligned with collective wellbeing rather than profit are not supplementary considerations; they are the conditions under which AI urbanism could begin to deliver on its sustainability promise.

This paper contributes to the critical AI urbanism literature by demonstrating that the paradox of algorithmic urban governance is not a technical malfunction but a structural feature of the political economies in which these systems operate. It advances the debate by proposing that genuine urban sustainability requires institutional transformations in data ownership, governance participation, and optimisation metrics, rather than incremental adjustments to existing algorithmic systems. For scholars of urban economics, the findings suggest that AI infrastructure investment follows the same logic of rent extraction and cost socialisation that characterises urban development more broadly: the question is not whether AI is good or bad for cities, but who captures the value it creates and who absorbs the costs it generates. Answering that question is both an analytical and a political task.

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