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Pockets of Excellence in Romanian Municipalities Between the New European Bauhaus and the AI Act

Akhilesh KUMAR SRIVASTAVA
Senior Research Scientist, PhD, Department of Process Technology, SINTEF Industry, SINTEF AS, Oslo, Norway
akhilesh.srivastava@sintef.no

Raluca ANTONIE[1]
Associate Professor, PhD, Department of Public Administration and Management, Faculty of Political, Administrative and Communication Sciences, Babeș-Bolyai University, Cluj-Napoca, Romania/ RATE AI LTD, Galway, Ireland
raluca.antonie@fspac.ro

Alex BUTEAN
Associate Professor, PhD, Department of Computer Science and Electrical Engineering, Faculty of Engineering, Lucian Blaga University of Sibiu, Romania / Wiz Development and Services SRL, Sibiu, Romania
alex@butean.com

Jared HANSEN
Project Manager, M.Sc. Mechatronics, Cody AS, Skien, Norway
jared@cody.no

Abstract:
The transition towards climate-neutral, circular and human-centric production systems requires effective multi-level governance, in which municipal administrations operate as enablers, regulators and orchestrators of local action. This article examines the institutional capacity of Romanian municipalities to operationalize three converging European Union policy frameworks, the New European Bauhaus (NEB), the Industry 5.0 agenda, and the EU Mission for 100 Climate-Neutral and Smart Cities, through decentralized sustainable manufacturing. The research combines a quantitative comparative analysis based on official Eurostat indicators (circular material use rate, municipal waste recycling rate, eco-innovation performance) and European Commission datasets (European Innovation Scoreboard 2025, EU Cities Mission Label register) with a qualitative instrumental case study of the Horizon Europe STARHAUS project, in which the Municipality of Cluj-Napoca participates as a pilot partner. The interdisciplinary author team combining expertise on process technology and digital twins, on digital innovation platforms, and on the mechatronic engineering of customized production equipment, with expertise on public administration, program evaluation and the emerging field of algorithmic impact assessment reflects the integrated nature of the inquiry. Findings reveal a structural paradox: Romania records the lowest circular material use rate in the European Union (1.3% in 2024, against an EU average of 12.2%) and ranks last on the Summary Innovation Index (37.7% of the EU average in 2025), yet hosts three cities admitted to the EU Cities Mission, with Cluj-Napoca among the first ten European cities to receive the EU Mission Label in October 2023. This decoupling suggests that municipalities can function as *pockets of governance excellence* within otherwise lagging national systems. The article proposes a four-layer multi-level governance framework, supranational design, national mediation, municipal operationalization, and citizen co-creation, and argues that EU cascade-funding instruments, NEB-inspired participatory methodologies, and an evaluation infrastructure that extends Social Impact Assessment with emerging Algorithmic Impact Assessment practices, in the context of the EU Artificial Intelligence Act, offer strategic levers for Romanian public administration to close the implementation gap.

Keywords: multi-level governance; New European Bauhaus; circular economy; EU Cities Mission; decentralized manufacturing; algorithmic impact assessment.

[1] Corresponding author

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INTRODUCTION

The transition of the European Union (EU) towards climate neutrality, circular resource use, and a human-centric industrial paradigm has produced a dense and partially overlapping policy architecture, articulated through the European Green Deal, the New European Bauhaus (NEB), the Industry 5.0 agenda (Breque et al., 2021), the Circular Economy Action Plan, and the five EU Missions under Horizon Europe. While these instruments are designed at the supranational level, their effectiveness ultimately depends on the institutional capacity of subnational administrations and, in particular, of municipalities, to translate strategic objectives into operational projects, regulations and procurement decisions. The local level is increasingly recognized as the space where systemic transformations either materialize or stall (European Commission, 2021; OECD, 2020).

Romania occupies a paradoxical position within this architecture. On the one hand, it consistently ranks at the bottom of EU sustainability and innovation indicators: in 2024, the country recorded the lowest circular material use rate in the Union (1.3%, against an EU average of 12.2%) (Eurostat, 2025a); in 2023, the lowest municipal waste recycling rate (12.4%) (Eurostat, 2025b); and, in 2025, the lowest Summary Innovation Index, with a performance of only 37.7% of the EU average (European Commission, 2025a). On the other hand, three Romanian cities – Cluj-Napoca, Suceava and București-Sector 2 – were selected among the 112 cities of the EU Mission for 100 Climate-Neutral and Smart Cities, and Cluj-Napoca was among the first ten European cities to receive the EU Mission Label, in October 2023, alongside Madrid, Stockholm, Mannheim, Klagenfurt, Sønderborg, Valencia, Valladolid, Vitoria-Gasteiz and Zaragoza (European Commission, 2023a; NetZeroCities, 2023). This decoupling between aggregate national indicators and local institutional dynamism raises a research question with direct administrative relevance: under what conditions can Romanian municipalities operationalize EU policy frameworks for sustainable, NEB-aligned, human-centric manufacturing, despite the structural lag of the national system? To address this question, the article combines a quantitative comparative analysis of Romania's position on EU sustainability and innovation indicators with an instrumental case study of the Horizon Europe STARHAUS project (Grant Agreement 101136027), in which the Municipality of Cluj-Napoca participates as a pilot partner alongside twelve organizations from seven European countries (Bratu et al., 2024). The case offers a rare opportunity to examine, in real time, how a Romanian municipality engages with the layered governance of NEB, Industry 5.0, the Cities Mission, and a Horizon Europe cascade-funding instrument.

A complementary inquiry runs in parallel throughout the analysis. The digital infrastructures that support contemporary decentralized manufacturing – digital twins, knowledge-graph platforms, machine-learning-based process control – fall within the scope of the Artificial Intelligence Act (Regulation (EU) 2024/1689), which introduces a risk-based regulatory regime for AI systems in the EU (European Union, 2024). This creates a new administrative challenge for municipalities that host such systems: in addition to traditional Social Impact Assessment (SIA), they require Algorithmic Impact Assessment (AIA) capacity to evaluate the rights-affecting, opaque, and adaptive characteristics of AI-enabled production systems (Reisman et al., 2018; Selbst, 2021). The article therefore reads STARHAUS through both lenses, SIA and emerging AIA, in order to identify the full evaluation infrastructure that a municipality such as Cluj-Napoca will need in order to absorb, regulate and learn from NEB-aligned innovation projects.

The article is the result of a deliberately interdisciplinary collaboration. Two of the authors contribute expertise on the technological pillar of STARHAUS process technology, modular manufacturing demonstration facilities, and digital-twin software platforms, while the other two contribute expertise on the administrative pillar, multi-level and adaptive governance, and program and algorithmic impact evaluation. This composition mirrors the integrated, S+T+ARTS-inspired nature of the New European Bauhaus itself, in which technology, governance and society are inseparable. The article proceeds as follows. Section 1 develops the conceptual framework. Section 2 describes the methodology and data sources. Section 3 presents the empirical findings in three sub-sections corresponding to the three layers of analysis: Romania's position in the EU sustainability and innovation landscape, the Romanian participation in the EU Cities Mission, and the STARHAUS case. Section 4 discusses policy implications. The conclusions outline contributions, limitations and further research directions.

1. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

1.1 The New European Bauhaus and multi-level governance

The New European Bauhaus, launched by the European Commission in 2020 and formalized through Communication COM (2021) 573 final, is a creative, transdisciplinary movement designed to bridge the European Green Deal with citizens' everyday environments through the integration of three core values: sustainability, aesthetics and inclusion (European Commission, 2021). Rosado-García et al. (2021) interpret the NEB as a culture of transversality oriented towards social, environmental and cultural sustainability, while Bratu et al. (2024) connect the NEB explicitly with the Fifth Industrial Revolution and frame the STARHAUS project as a paradigmatic case of NEB principles in action.

From a public administration perspective, the NEB is not a sectoral policy but a horizontal frame that requires coordination across levels of government and across policy domains (urban planning, industrial policy, education, social inclusion). It thus operates within a multi-level governance (MLG) logic, in which the European, national, regional and local layers share competences and resources for the production of public value (Hooghe & Marks, 2003). The MLG perspective is consistent with the dominant view in the literature on the governance of sustainability transitions, where co-creation and experimentation are seen as central instruments of urban transformation (Frantzeskaki et al., 2017; von Wirth et al., 2018).

In the Romanian context, Țiclău, Hințea and Andrianu (2020) have argued that adaptive and turbulent governance characterized by responsiveness, flexibility and openness to participatory mechanisms has become a necessary mode of administrative action when complex, cross-cutting challenges meet weakly institutionalized policy environments. This perspective is directly relevant for the present analysis: a city like Cluj-Napoca demonstrates adaptive capacity precisely by absorbing successive EU policy frames (NEB, Cities Mission, Industry 5.0, Horizon Europe) without waiting for the national system to consolidate its own response. In parallel, Vlad, Hințea, Neamțu and Stănică (2023) have documented, in a comparative US-Romania study, how digital media reshape the relationship between local government and citizens, opening new channels for participatory governance, a dimension that becomes particularly salient when decentralized manufacturing platforms with citizen-facing digital interfaces are introduced in urban environments. Building on the broader literature on participatory planning and co-creation of public services (Torfing, Sørensen, & Røiseland, 2019), Voinea, Profiroiu and Profiroiu (2022) have shown, on the basis of qualitative research conducted with civic initiative groups in Bucharest during the COVID-19 pandemic, that public participation in Romania is shaped by a persistent adversarial relationship between citizens and local authorities, while genuine collaborative co-creation, although recognized as the normative ideal, remains the exception rather than the rule. This empirical observation defines the institutional gap that NEB-aligned, project-based forms of decentralized manufacturing must navigate at municipal level.

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1.2 Decentralized sustainable manufacturing and Industry 5.0

The concept of Industry 5.0, articulated by the European Commission through the policy brief of Breque et al. (2021), reframes industrial policy around three pillars: human-centricity, sustainability and resilience. In contrast with the productivity-focused agenda of Industry 4.0, Industry 5.0 explicitly subordinates technological development to social and environmental objectives. Nahavandi (2019) and Longo et al. (2020) emphasize the ethical and value-oriented dimensions of this paradigm, while Lu et al. (2022) develop a comprehensive framework for human-centric manufacturing systems based on collaboration, customization and co-creation.

From the technological standpoint, the operationalization of Industry 5.0 at urban scale relies on three complementary infrastructures. First, modular Manufacturing Demonstration Facilities (MDFs) (small-scale, reconfigurable production units that integrate powder, liquid and particulate handling technologies) make it physically possible to deploy customized production close to the point of consumption. The technological lineage of STARHAUS's MDFs builds on prior process-technology work at SINTEF, including the Horizon 2020 DIY4U project, on which the technology readiness level was earlier developed and validated (Bratu et al., 2024). Second, the realization of such MDFs as actual production equipment depends on specialized mechatronic engineering capable of integrating mechanical design, robotics, automation, industrial IT and complex system integration in machines that perform multiple operations in a compact spatial footprint. This is precisely the engineering profile that Norwegian engineering firms such as Cody AS, with a long-standing track record in customized production equipment for regulated industries, bring to consortia of the STARHAUS type. Third, the digital layer that orchestrates such facilities relies on digital-twin frameworks that integrate sensor data, knowledge graphs and simulation pipelines, as recently demonstrated by Lam et al. (2025) in the SINDIT framework developed within the COGNIMAN project, and by Matei et al. (2025) in a conceptual architecture for high-temperature heat upgrade systems. These three technological strands (process technology, mechatronic integration, and cognitive digitalization) together constitute the enabling infrastructure of any decentralized, NEB-aligned manufacturing strategy.

Beyond their technical architecture, MDFs carry two further advantages of direct relevance for the NEB pillars of sustainability and inclusion. First, MDF customers will be able to make informed, low-emission choices from the start, as product-level environmental information can be surfaced at the design and purchase interface and incorporated into the customization decision itself. Second, this approach promotes inclusion by enabling consumers who do not find suitable off-the-shelf products to design and produce products customized to their needs, an outcome consistent with the human-centric ambition of Industry 5.0 and with the participatory dimension of the New European Bauhaus.

Crucially, the digital layer of such systems increasingly relies on machine-learning components for predictive maintenance, process optimization and quality control. Under the Artificial Intelligence Act (Regulation (EU) 2024/1689), AI systems deployed as safety components of products covered by Union harmonisation legislation, a category that includes food, feed and certain consumer goods, are classified as high-risk AI systems and trigger obligations on providers and deployers in terms of risk management, data governance, transparency, human oversight and post-market monitoring (European Union, 2024). When a municipality acts as host or deployer of such systems, these obligations become administratively relevant, a point developed in Section 4.2.

For municipalities, decentralized manufacturing represents a policy lever with direct administrative consequences: it interacts with land-use regulation, environmental permitting, public procurement, food safety, consumer protection and local economic development. STARHAUS operationalizes this approach through four use-cases in the fast-moving consumer goods (FMCG) sector – pet food, fertilizers, beverages and breakfast cereals, produced via MDFs intended to be deployed in urban communities (Bratu et al., 2024). The combination of a physically present production unit and a citizen-facing digital interface generates a hybrid public-private space that traditional regulatory categories struggle to accommodate.

1.3 Circular economy, program evaluation and algorithmic impact assessment in cities

The circular economy (CE) literature has expanded rapidly since the seminal contribution of Kirchherr et al. (2017), which identified 114 distinct definitions and proposed an integrative formulation centered on micro, meso and macro levels of intervention. Mayer et al. (2019) developed a monitoring framework for economy-wide material loop closing in the EU, which constitutes the methodological backbone of Eurostat's circular material use rate (CMUR) indicator. At urban level, Williams (2019) maps the structural challenges of implementing looping actions in cities, while Lakatos et al. (2021), building on extensive Romanian fieldwork (Lakatos et al., 2018) , propose a holistic framework for circular cities that links resource flows, governance arrangements and citizen behaviour.

Three observations from this literature are particularly relevant for the present analysis. CE policies require active municipal stewardship, since cities concentrate both material flows and citizen demand (Lakatos et al., 2021; Williams, 2019). The social dimension of CE, including consumer attitudes, behavioural change and equity remains under-investigated relative to the technological and economic dimensions (Lakatos et al., 2018). The implementation of CE at urban level is heavily dependent on the coordination capacity of local administrations, including their ability to mobilize EU funding instruments and to engage civil society (OECD, 2020).

Another observation, central to the present article, concerns the evaluation infrastructure that municipalities need in order to learn from NEB-aligned interventions. Antonie (2012) has proposed a Social Impact Assessment (SIA) model specifically calibrated for public administration reform in Romania, building on the international SIA tradition and adapting it to the institutional realities of post-transition Romanian municipalities. The SIA framework distinguishes the direct outputs of an intervention from the indirect, longer-term, often counterfactual social effects that determine whether a policy actually changes citizen practices. This distinction is decisive for projects of the STARHAUS type, where the explicit objective is not only to deploy a technology but to alter consumption habits and to foster behavioural change.

A different perspective, on which the present analysis places particular emphasis, concerns the extension of impact assessment to algorithmic systems. As public services and decentralized infrastructures increasingly rely on AI-enabled components, scholars and policy-makers have developed the framework of Algorithmic Impact Assessment (AIA) as a regulatory and learning instrument designed to anticipate, document and mitigate the social harms of algorithmic systems (Reisman et al., 2018). Selbst (2021), writing from an institutional governance perspective, argues that AIA cannot be reduced to a technical exercise: it requires regulatory frameworks that combine pre-deployment review, public disclosure, due-process challenge mechanisms and longitudinal monitoring, all of which depend on the administrative capacity of the public bodies hosting the AI systems. The structural analogy between AIA and SIA is methodologically productive: both rest on a three-layer logic (outputs / outcomes / systemic effects), both require participatory consultation, and both depend on counterfactual reasoning. For Romanian municipalities, an integrated SIA-plus-AIA evaluation infrastructure constitutes an emerging research and administrative priority, particularly in light of the staggered entry into application of the EU AI Act between 2025 and 2027 (European Union, 2024).

2. METHODOLOGY

The article adopts a mixed-methods research design, combining a quantitative comparative analysis of secondary data with a qualitative instrumental case study. The two strands are complementary: the quantitative analysis maps Romania's structural position within the EU on a coherent set of sustainability and innovation indicators, while the case study illustrates how a Romanian municipality navigates this position through a concrete Horizon Europe project.

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All quantitative data used in this article were retrieved from official European Union sources and the dates of access and dataset identifiers are reported here in full, in line with the principles of transparent and replicable research. The circular material use rate refers to Eurostat dataset cei_srm030, as published in the Eurostat news release of 19 November 2025; the recycling rate of municipal waste refers to Eurostat datasets cei_wm011 and env_wasmun (reference year 2023); the composition of municipal waste refers to Eurostat dataset env_wasobl (reference year 2023). Innovation indicators refer to the European Innovation Scoreboard 2025 country profile for Romania and the Regional Innovation Scoreboard 2025 regional profile for Romania, both published by the European Commission, Directorate-General for Research and Innovation, in 2025. Municipal waste profile data are drawn from the European Environment Agency's Romania country fact sheet of 2025. EU Cities Mission Label data are drawn from the European Commission Research and Innovation news releases of 5 October 2023 and 7 May 2025, and from NetZeroCities communications of October 2023. All sources were last consulted in 2026 for the purposes of this article.

The qualitative case study focuses on the STARHAUS project (HORIZON-CL4-2023-HUMAN-01-53, Grant Agreement 101136027), with particular attention to the Municipality of Cluj-Napoca (MCLUJ) as pilot partner. The principal documentary source is the peer-reviewed article published by Bratu et al. (2024) in the *Transylvanian Review of Administrative Sciences*, which provides a project-internal description of the consortium, objectives and governance arrangements; this is complemented by publicly available European Commission information on the New European Bauhaus and the EU Cities Mission, and by Cluj-Napoca's Climate City Contract endorsement of October 2023 as reported by the European Commission and NetZeroCities. The case is treated as instrumental in the sense of Stake (1995): the interest lies not in Cluj-Napoca per se, but in what the case reveals about the broader dynamics of Romanian municipal governance vis-à-vis EU sustainability frameworks.

The evaluation lens adopted for the case study draws on the Social Impact Assessment (SIA) model proposed by Antonie (2012), which distinguishes three main layers of intervention effects: (i) direct outputs (products, prototypes, events); (ii) intermediate outcomes (changes in attitudes, knowledge, behaviour among directly involved citizens); and (iii) systemic impacts (changes in institutional practice, regulatory frameworks, or cross-municipal learning). For the technological layer of the project, this lens is complemented by an Algorithmic Impact Assessment (AIA) perspective informed by Reisman et al. (2018), Selbst (2021), and the legal framework of the EU Artificial Intelligence Act (European Union, 2024). The combined SIA-AIA lens is used to identify which administrative routines a municipality would need to institutionalize in order to capture the full social and algorithmic impact of an NEB-aligned project.

The research is exploratory and descriptive in nature, and does not seek statistical generalization. Its analytical added value lies in the systematic juxtaposition of three layers of evidence (national-level structural indicators, EU-level municipal performance signals, and project-level operationalization) that are usually treated in isolation in the literature. The interdisciplinary composition of the author team (process-technology and digital-twin expertise from SINTEF; digital-platform expertise from the Lucian Blaga University of Sibiu and Wiz Development and Services; mechatronic engineering of customized production equipment from Cody AS; public administration, program evaluation and emerging research on algorithmic impact assessment from the Faculty of Political, Administrative and Communication Sciences at Babeș-Bolyai University) is itself a methodological resource: it ensures that the same project is read simultaneously through the lens of what is technologically feasible and what is administratively and legally absorbable.

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3. RESULTS

3.1 Romania's position in EU sustainability and innovation indicators

The first layer of analysis examines Romania's position within the EU on a coherent set of indicators of structural relevance for the transition towards sustainable and circular manufacturing. Table 1 presents the comparative figures for the most recent reference year available.

Table 1. Romania in the EU sustainability and innovation landscape (latest available data)

Indicator	Reference year	Romania	EU average	RO rank (EU-27)
Circular material use rate (CMUR)	2024	1.3%	12.2%	27 (last)
Municipal waste recycling rate	2023	12.4%	48.0%	27 (last)
Municipal waste generated per capita	2023	305 kg	511 kg	1 (lowest generation)
Biowaste share of municipal waste	2023	58.4%	varies	1 (highest)
Summary Innovation Index 2025 (EU=100)	2025	37.7	100.0	27 (last)
Production-based CO_2 productivity (EU=100)	2025	123.3	100.0	9
Business R&D expenditure (EU=100)	2025	19.3	100.0	27 (last)

Source: authors' compilation based on Eurostat (2025a, 2025b, 2025c), European Commission (2025a, 2025b), European Environment Agency (2025), as consulted in 2026.

The data reveal a coherent pattern of structural lag. With a circular material use rate of only 1.3% in 2024, Romania is nearly ten times below the EU average of 12.2% and at the bottom of a Union-wide ranking otherwise led by the Netherlands, Belgium and Italy (Eurostat, 2025a). The Circular Economy Action Plan target of doubling the EU CMUR by 2030 appears, against this background, structurally distant for Romania.

The picture is reinforced by waste management indicators. Romania's municipal waste recycling rate was 12.4% in 2023, against an EU average of 48.0%; the country thus enters the trajectory towards the EU recycling targets set by the Waste Framework Directive with a substantial deficit (Eurostat, 2025b). Romania also records the lowest municipal waste generation per capita in the EU (305 kg, against 511 kg EU average), which reflects different consumption patterns and lower per-capita disposable income, but is not in itself an indicator of circular performance. The high share of biowaste in municipal waste (58.4%, the highest in the EU) is particularly relevant for projects such as STARHAUS, whose use-cases involve food and food-adjacent products and therefore intersect with the bio-waste cycle (European Environment Agency, 2025).

On innovation indicators, the European Innovation Scoreboard 2025 classifies Romania as an Emerging Innovator with an index value of 37.7 (EU = 100), the lowest absolute position in the Union (European Commission, 2025a). Romania's profile is heterogeneous: while it ranks last on business R&D expenditure (19.3% of the EU average), it performs strongly on production-based CO_2 productivity (rank 9, 123.3% of EU average), an indicator that captures the decarbonization performance of the productive system. This contrast suggests that the structural conditions for decarbonization exist, but are not translated into systemic innovation capacity.

The Regional Innovation Scoreboard 2025 further reveals that innovation capacity within Romania is highly concentrated: București-Ilfov is the country's most innovative region and the only Emerging+ region; the remaining seven regions are classified as Emerging- (European Commission, 2025b). This concentration is an analytically relevant fact: it implies that municipal-level dynamism – including in cities outside the capital, such as Cluj-Napoca – is uneven and partially decoupled from the regional aggregate.

3.2 The EU Cities Mission and Romanian participation

The EU Mission for 100 Climate-Neutral and Smart Cities is one of the five EU Missions under Horizon Europe, launched on 28 April 2022 with the selection of 112 cities (100 from EU Member States and 12 from countries associated to Horizon Europe). The Mission Label is awarded after the review of a city's Climate City Contract (CCC), a strategic document developed in co-creation with local stakeholders, and has become a recognized signal of municipal governance maturity and a passport to additional EU, national and private funding (European Commission, 2025c; NetZeroCities, 2023).

Romania has three cities participating in the Mission: Cluj-Napoca, Suceava and București-Sector 2. Cluj-Napoca was one of only ten cities to receive the Mission Label in the first round, on October 2023, alongside Madrid, Stockholm, Mannheim, Klagenfurt, Sønderborg, Valencia, Valladolid, Vitoria-Gasteiz and Zaragoza (European Commission, 2023a; EIT Climate-KIC, 2023). A further 39 cities received the Mission Label in May 2025 (European Commission, 2025c). Table 2 summarizes the Romanian footprint in the Mission as of the most recent publicly available European Commission communications consulted for this article.

Table 2. Romanian participation in the EU Mission for Climate-Neutral and Smart Cities

City	Mission selection (April 2022)	EU Mission Label status (based on public EC communications consulted in 2026)
Cluj-Napoca	Yes	Awarded, October 2023 (first batch of ten cities)
Suceava	Yes	Not yet listed among the labelled cities in the EC communications consulted
București-Sector 2	Yes	Not yet listed among the labelled cities in the EC communications consulted

Source: authors' compilation based on European Commission (2023a, 2025c), EIT Climate-KIC (2023), NetZeroCities (2023).

Three main analytical observations follow. Romania's three Mission cities cover three distinct administrative archetypes: a major non-capital city (Cluj-Napoca), a smaller regional capital (Suceava), and an urban district of the capital (București-Sector 2). This diversity, although limited in absolute numbers, offers a useful experimental basis for the development of differentiated municipal capacities, with broader replication potential across the country.

The early labelling of Cluj-Napoca confirms a pattern of municipal governance dynamism that long preceded the Mission. The city submitted its Climate City Contract in April 2023 and obtained Commission endorsement six months later, on the basis of a review carried out with the support of the European Investment Bank and the Joint Research Centre (European Commission, 2023a). Institutionally, Cluj-Napoca had previously developed instruments such as the Centre for Innovation and Civic Imagination, in partnership with the Cluj Cultural Centre, with the support of the Urban Innovative Actions Initiative (European Commission, 2023b). These instruments illustrate, in administrative terms, the cumulative effect of long-term institutional learning, consistent with the adaptive governance perspective elaborated by Ţiclău et al. (2020).

The institutional convergence between the Cities Mission framework and the STARHAUS consortium coordinated by SINTEF, an Oslo-based research organization, illustrates the logic of EU policy ecosystems that increasingly reward, and reinforce, prior governance relationships (Janssen et al., 2021). A municipality that signals administrative maturity through the Mission Label becomes a credible candidate for parallel Horizon Europe projects, in a self-reinforcing dynamic that deserves systematic empirical investigation across the three Romanian Mission cities.

3.3 STARHAUS as case study: decentralized manufacturing meets municipal governance

The STARHAUS project (Sustainable, Technological, Accessible and Resilient Human-Centric Manufacturing Supporting the New European Bauhaus through Synergies between Customized Production and Consumption Models), funded under Horizon Europe Cluster 4 (HORIZON-CL4-2023-HUMAN-01-53), Grant Agreement 101136027, is implemented by a consortium of thirteen partners from seven European countries (Norway, Italy, Portugal, Spain, France, Bulgaria and Romania) (Bratu et al., 2024). The project deploys two Manufacturing Demonstration Facilities (MDFs) – modular, small-scale, urban-deployable production units – in two pilot locations: the Comunidade Intermunicipal da Região de Coimbra (Portugal) and the Municipality of Cluj-Napoca (Romania). The four use-cases addressed are pet food, fertilizers, beverages and breakfast cereals (Bratu et al., 2024).
From the perspective of process technology, STARHAUS adapts an existing platform, validated under previous H2020 work in the area of customized consumer goods, to new product categories that require the redesign of mixing and dispensing modules, the recalibration of process simulation tools, and the integration of regulatory constraints specific to food, feed and fertilizer products (Bratu et al., 2024). From the perspective of mechatronic engineering, this translation into urban-deployable equipment requires customized machine design, robotic handling subsystems and modular control architectures capable of operating in non-industrial environments (retail, civic spaces, community facilities) while complying with the standards of regulated production. On the software side, the platform builds on a digital-twin lineage that includes recent contributions to knowledge-graph-based digital twin architectures (Lam et al., 2025) and conceptual digital-twin approaches for sustainable industrial systems (Matei et al., 2025). From an administrative sciences perspective, this technological depth is consequential: it means that a host municipality is not engaging a generic 'innovation event', but a mature, multi-disciplinary technological infrastructure with a multi-project track record, a circumstance that strengthens the case for municipal absorption.

Table 3 maps the convergence of EU policy frameworks in STARHAUS against the administrative implications for the Municipality of Cluj-Napoca, including the implications associated with the entry into application of the EU Artificial Intelligence Act.

Table 3. Convergence of EU policy frameworks in STARHAUS, with administrative implications for the Municipality of Cluj-Napoca

EU policy framework	Operationalization in STARHAUS	Administrative implication for the host municipality
New European Bauhaus (NEB)	Cross-disciplinary methods combining design, sustainability and inclusion; participatory co-design with citizens, artists and engineers.	Institutional capacity in co-design facilitation, intersectoral coordination (urban planning, culture, innovation), and integration of NEB criteria in local procurement and urban regeneration calls.
Industry 5.0	Adaptation of two MDFs to new product categories; human-centric customization; digital-twin software platform; integration of social sciences and humanities across work packages.	Regulatory mediation between modular small-scale production and existing legal frameworks (food safety, environmental permits, consumer protection); local economic development strategy linking SMEs and decentralized manufacturing.
EU Cities Mission / circular economy	Project activities aligned with the climate-neutral and circular city agenda; life-cycle environmental footprint improvement; longitudinal social monitoring.	Embedding of project deliverables in the Climate City Contract; use of the Mission Label as leverage for additional public-private investment; institutionalization of

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EU policy framework	Operationalization in STARHAUS	Administrative implication for the host municipality
		citizen Knowledge-Attitude-Practice (KAP) surveys.
EU Artificial Intelligence Act (Reg. (EU) 2024/1689)	AI components embedded in the digital-twin platform and in MDF process control; AI-supported optimization and monitoring of production.	Establishing Algorithmic Impact Assessment capacity; documenting risk classification of the AI components; ensuring human oversight, transparency and post-market monitoring in line with the EU AI Act obligations applicable to deployers.
Horizon Europe cascade funding (FSTP)	Financial Support to Third Parties for the engagement of local actors; S+T+ARTS-style residencies bringing artists and scientists together.	Municipal role in dissemination, applicant engagement and mentoring of local SMEs and start-ups; alignment of FSTP scheme with the local innovation ecosystem (universities, makerspaces, civic innovation centres).

Source: authors' analysis based on Bratu et al. (2024) and the EU policy frameworks cited in the table.

Reading the project through the SIA lens of Antonie (2012) reveals a three-layer impact architecture. At the level of direct outputs, STARHAUS commits to prototypes, hardware modules, residencies and a set of FSTP-funded sub-projects (Bratu et al., 2024). At the level of intermediate outcomes, the project foresees a programme of semi-structured interviews, focus groups and pre- and post-intervention KAP surveys, all designed to track changes in citizens' knowledge, attitudes and consumption practices. At the level of systemic impact, the project commits to improvements in the life-cycle environmental footprint of the new products and to the production of an anonymized open dataset that documents the social trajectory of the intervention.

This three-layer structure is administratively significant. The first layer (outputs) is largely under the control of the consortium and is comparatively easy to measure. The second layer (outcomes) is partially under the control of the municipality, which mediates citizen participation through local channels, and where the digital governance literature on Romanian rural and urban settings (Vlad et al., 2023) becomes operationally relevant. The third layer (systemic impact) is realistic only if the municipality embeds project deliverables in its Climate City Contract and in its standing administrative routines (e.g., green public procurement, school catering programmes). Without this embedding, even successful pilots tend to dissipate after project closure, a well-documented pattern in EU-funded innovation work (Janssen et al., 2021).

Reading the same project through the AIA lens (Reisman et al., 2018; Selbst, 2021; European Union, 2024) reveals a parallel, technologically-driven impact architecture that the traditional SIA framework cannot fully capture. The digital-twin platform supporting the MDFs is itself an AI-enabled system whose data pipelines, optimization routines and recommendation functions can affect product quality, food-safety outcomes, consumer choice and the working conditions of municipal staff interacting with the system. Under Regulation (EU) 2024/1689, key obligations – risk-management system, data governance, transparency, human oversight, post-market monitoring – apply with full force only from August 2026 (and, for AI systems embedded in regulated products, from August 2027 or 2028 according to the most recent implementing provisions), but the institutional design choices that make compliance feasible must be made well in advance. For a municipality, this implies the need to inventory the AI systems it hosts, to classify their risk level, to define oversight roles, and to participate in the post-market monitoring framework.

Cluj-Napoca's role in STARHAUS therefore exceeds the standard 'pilot location' framing. The municipality acts simultaneously as host, regulator, intermediary with local civil society, communication node, and co-author of the project's social impact dataset, while also being positioned as one of the first European municipalities at which the combined application of SIA and AIA to an NEB-aligned, AI-enabled manufacturing project becomes operationally testable. This integrated role is consistent with the conception of municipalities as orchestrators of urban transitions developed in the recent literature on circular cities (Lakatos et al., 2021; Williams, 2019), with the adaptive governance perspective elaborated in the Romanian public administration literature (Țiclău et al., 2020), and with the broader move towards municipal-level algorithmic accountability in the international literature on AI governance (Selbst, 2021).

4. DISCUSSION

4.1 A four-layer multi-level governance framework

The findings support the articulation of a four-layer multi-level governance framework for the operationalization of NEB-aligned decentralized manufacturing. The supranational layer (European Commission, Horizon Europe Mission Boards, the NEB Initiative, the AI Office) provides the strategic frame, the funding architecture, the labelling instruments and the risk-based regulatory regime (European Union, 2024; Janssen et al., 2021; Mazzucato, 2018). The national layer (line ministries, national managing authorities) mediates between supranational instruments and subnational territories, but in Romania demonstrates limited capacity to compensate for the country's structural lag on circular and innovation indicators (European Commission, 2025a). The municipal layer operationalizes the policies through regulation, procurement, public space and partnerships with research and civil society organizations; this is the level at which the case of Cluj-Napoca demonstrates that pockets of excellence can emerge. The citizen layer ultimately validates and sustains the transition through behavioural change, civic participation, and consumption practices (Lakatos et al., 2018; Țiclău et al., 2020).

The most analytically interesting finding is the relative autonomy of the municipal layer with respect to the national layer. While Romania is structurally behind on most aggregate indicators, the early labelling of Cluj-Napoca under the Cities Mission and the city's participation in STARHAUS demonstrate that local administrative capacity can be cultivated through long-term institutional learning, even in the absence of strong national mediation. This is in line with Bratu et al. (2024), who frame STARHAUS as an example of adaptive governance, and with Țiclău et al. (2020), who argue that resilience in public administration depends on the capacity for context-sensitive adaptation.

4.2 Policy implications for Romanian municipal administration

Five key policy implications follow from the analysis. Green public procurement remains under-exploited. Given Romania's very low CMUR and recycling rates, the use of procurement criteria favouring recycled materials, modular and repairable products, and short-supply-chain food procurement could create local demand that compensates for the limited national regulatory pressure. STARHAUS's FMCG use-cases offer concrete pilot scenarios for such procurement strategies.

Regulatory mediation is a critical municipal competence. Decentralized, small-scale, modular manufacturing of food and food-adjacent products encounters legal frameworks designed for large-scale industrial production. Municipalities can act as one-stop intermediaries between project consortia and national regulatory authorities, accelerating permitting and clarifying the legal status of in-store, point-of-sale customized production. The digital-twin infrastructures discussed in Section 1.2 (Lam et al., 2025; Matei et al., 2025) offer an additional regulatory affordance: by generating a real-time, auditable record of inputs, parameters and outputs, they make it technically possible for municipal authorities to monitor compliance without paralysing experimentation.

Citizen co-design must be institutionalized beyond the project cycle. The methodologies developed within STARHAUS, such as KAP surveys, design sprints, S+T+ARTS residencies, focus groups should be embedded in routine municipal practice, rather than treated as project deliverables. Cluj-Napoca's Centre for Innovation and Civic Imagination provides a pre-existing institutional anchor for this purpose (European Commission, 2023b). The literature on participatory and digital governance in Romania (Vlad et al., 2023) confirms that municipal-level digital tools can substantially expand the radius of citizen engagement, provided that the institutional design is aligned with citizens' actual media practices. The empirical findings of Voinea, Profiroiu and Profiroiu (2022) reinforce this implication from a complementary angle: among Romanian civic initiative groups, co-initiation tends to be the most resilient form of co-creation under external shocks, while the more demanding forms, co-design and co-implementation, require sustained, institutionalized commitment on the side of the municipality. For an NEB-aligned project such as STARHAUS, this suggests that the municipality should not limit itself to enabling co-initiation, but should actively scaffold the transition of citizen involvement towards co-design and co-implementation, including through stable budgets, dedicated staff and recurring formats of engagement that survive electoral cycles.

The evaluation infrastructure must be upgraded through the institutionalization of Social Impact Assessment. The SIA framework developed by Antonie (2012) provides a Romania-calibrated methodology for distinguishing direct outputs from intermediate outcomes and systemic impacts. Embedding such a framework in the routine work of municipal innovation departments would allow Cluj-Napoca and the other two Romanian Mission cities to produce comparable, longitudinal evidence of the effects of NEB-aligned interventions, an evidence base that is currently absent at national level. This is consistent with the recommendations of the OECD (2020) for circular economy governance in cities, which place evaluation infrastructure on a par with strategic planning.

The most central to the present article's contribution to the public administration literature, Romanian municipalities will require an Algorithmic Impact Assessment capacity in the period 2026-2028, as the obligations of the EU Artificial Intelligence Act become progressively applicable (European Union, 2024). The institutional logic of AIA, as developed by Reisman et al. (2018) and refined by Selbst (2021), implies that AIA is not a one-off compliance check but a continuous administrative function that combines pre-deployment risk classification, public disclosure, mechanisms for due-process challenge, and longitudinal monitoring of algorithmic outputs. For a municipality that hosts AI-enabled manufacturing infrastructure such as the STARHAUS MDFs, this function intersects directly with the SIA function: both are forms of impact assessment, both operate on a three-layer (outputs/outcomes/systemic) logic, and both depend on the same administrative capacities of data governance, stakeholder consultation and counterfactual reasoning. The development of an integrated SIA-AIA framework, calibrated for Romanian municipalities and for the specific risk profile of decentralized, NEB-aligned manufacturing, constitutes an open research and policy agenda in which administrative scientists and AI governance scholars can work jointly.

4.3 Limitations

Several limitations of the present analysis should be noted. First, the empirical material refers primarily to a single Romanian municipality and to a project that, at the time of writing, is in its implementation phase; the medium- and long-term outcomes of STARHAUS cannot yet be evaluated. Second, the analysis relies on official statistical sources whose methodologies, in particular for circular economy indicators, are themselves subject to revision (Mayer et al., 2019); future Eurostat updates may alter the comparative picture. Third, the article focuses on Romania and on the EU governance framework; broader generalizations to non-EU contexts, or to municipal systems with different competence allocations, require additional comparative research. Fourth, the AIA dimension is treated as an emerging policy and research direction rather than as an applied empirical exercise, because the relevant EU AI Act obligations are not yet fully in application and the operational AIA practice in EU municipalities remains in an early stage of institutionalization.

5. CONCLUSIONS

This article has examined the institutional capacity of Romanian municipalities to operationalize the converging EU policy frameworks of the New European Bauhaus, Industry 5.0, the Mission for Climate-Neutral and Smart Cities, and the Artificial Intelligence Act, in the field of decentralized sustainable manufacturing. The combination of comparative analysis based on Eurostat and European Commission datasets with an instrumental case study of the Horizon Europe STARHAUS project reveals a structural paradox of Romanian public administration: aggregate national indicators on circular economy and innovation place the country at the bottom of the European Union, while a small but visible number of municipalities operate at a level of governance maturity comparable to European Mission frontrunners.

Three main contributions follow from the analysis. First, the article documents, on the basis of verified official data, the magnitude of the gap between Romania's national-level structural position and its municipal-level performance in the EU Cities Mission. Second, it proposes a four-layer multi-level governance framework (supranational, national, municipal, citizen) that allows researchers and practitioners to position concrete projects such as STARHAUS within the broader European architecture. Third, it derives five policy implications for Romanian municipal administration: the strategic use of green public procurement, the institutionalization of regulatory mediation supported by digital-twin auditability, the embedding of citizen co-design beyond the project cycle, the upgrade of the evaluation infrastructure through the use of Social Impact Assessment methodologies adapted to the Romanian context, and the development of an Algorithmic Impact Assessment capacity at municipal level in light of the EU Artificial Intelligence Act.

Further research could pursue three directions. A comparative analysis of the three Romanian Cities Mission participants (Cluj-Napoca, Suceava, București-Sector 2) would test the replicability of the patterns observed in Cluj-Napoca. A longitudinal evaluation of STARHAUS at project closure, guided by the three-layer SIA framework, would allow the verification of the social impact assumptions formulated in the project's logical framework. Finally, the development and empirical validation of an integrated SIA-AIA evaluation framework for Romanian municipalities, capable of capturing both the social and the algorithmic dimensions of NEB-aligned interventions, constitutes a particularly promising research direction at the intersection of public administration, program evaluation and AI governance studies.

AUTHORS CONTRIBUTIONS

The authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. A.K.S. led the analysis of the process-technology pillar of STARHAUS, including the lineage of the Manufacturing Demonstration Facilities and the digital-twin research infrastructure, and contributed to the discussion of Industry 5.0 in Section 1.2. R.A. led the methodological design based on Social Impact Assessment (Section 2), the three-layer reading of STARHAUS outcomes (Section 3.3), the integration of the emerging Algorithmic Impact Assessment perspective with the SIA framework (Sections 1.3, 3.3, 4.2), and the policy implications on evaluation infrastructure. A.B. led the analysis of the digital-platform component and the digital governance implications discussed in Section 4.2, and coordinated the case-study documentation on STARHAUS. J.H. led the analysis of the mechatronic engineering pillar, including the customized production-equipment perspective on the MDFs and the discussion of compact, urban-deployable industrial systems, through Sections 1.2 and 3.3. All authors contributed to the conceptualization, the empirical analysis, the discussion, the conclusions, and the revision of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. A.K.S., A.B. and J.H. are affiliated with organizations that participate in, or contribute engineering services to, the STARHAUS consortium, which constitutes the case study of the present article; this involvement is disclosed for transparency but did not influence the analytical findings, which rely on independently verifiable secondary data sources.

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