

DIGITAL WASTE LOGISTICS AND METROPOLITAN GOVERNANCE IN ISTANBUL

Fabian BEHRENDT

*Department of Economics, Magdeburg-Stendal University of Applied Sciences, Magdeburg,
Germany
fabian.behrendt@h2.de*

Cumhur DÜLGER

*Department of Economics, Magdeburg-Stendal University of Applied Sciences, Germany
cumhur.dulger@gmail.com (corresponding author)*

Abstract

Urban waste management systems are increasingly shaped by digitalisation initiatives aimed at improving efficiency, transparency, and environmental performance, yet the operational impacts of digital technologies depend critically on the governance structures and organisational scale within which they are embedded. This study examines how a highly centralised metropolitan governance model conditions the role of digital waste logistics technologies, using Istanbul's metropolitan waste management system (İSTAÇ) as an in-depth single case. Drawing on publicly available sustainability and operational reports, the analysis applies qualitative content analysis and indicator-based interpretation to examine how organisational centralisation, decision-making hierarchies, and metropolitan scale shape the operational function of digital tools. The findings show that in large, hierarchically governed systems, digitalisation primarily supports system-wide coordination, monitoring, and reporting rather than micro-level operational flexibility: digital technologies function as instruments of institutional reinforcement rather than transformation, amplifying existing governance logics. These results offer a theoretically grounded, empirically anchored account of how governance design conditions the outcomes of digitalisation in metropolitan-scale public services, and highlight the limits of scale-neutral policy prescriptions in digital waste logistics.

Keywords: Urban waste logistics; Metropolitan governance; Digitalisation; Organisational centralization; Istanbul

1. INTRODUCTION

Urban waste management systems are increasingly shaped by digitalisation initiatives aimed at enhancing efficiency, transparency, and environmental performance. Technologies such as GPS/GPRS-enabled fleet management, real-time monitoring, and route optimisation are widely promoted as instruments for reducing costs, emissions, and service disruptions in municipal waste logistics (McKinnon et al. 2015; Wilson, Velis, & Cheeseman 2006), and are often portrayed in policy discourse as scale-neutral interventions transferable across urban contexts with comparable efficiency gains (European Commission 2018).

Empirical experience, however, indicates that the operational effects of digital waste logistics technologies are far from uniform. Cities differ substantially in scale, organisational structure, and governance capacity, raising fundamental questions about how digitalisation interacts with existing institutional arrangements (Bulkeley & Betsill 2005; Bulkeley, Castán Broto, & Edwards 2015; Pierre 2011).

This study argues that urban scale and governance structure critically mediate the effects of digital waste logistics technologies. The literature review below develops this argument by situating it within the literature on digitalisation, urban governance, and metropolitan coordination.

The article pursues this argument through an in-depth single case analysis of Istanbul's metropolitan waste management system, operated by İSTAÇ (Istanbul Environmental Management Industry and Trade Inc.). Istanbul is an especially revealing case: waste management operates there at exceptional scale, its governance model concentrates planning, fleet management, transfer operations, and reporting within a single metropolitan company, and its recent reports provide unusually detailed public documentation of how digital tools are embedded within this structure.

The study does not benchmark Istanbul's performance against other cities. Instead, it adopts a governance-oriented analytical approach, examining how organisational centralisation, decision hierarchies, and metropolitan scale shape the functional role of digital technologies in waste logistics operations, drawing on İSTAÇ's published reports analysed through qualitative content analysis supplemented by illustrative operational ratios.

The findings contribute to urban governance and public management debates by demonstrating that digital transformation in metropolitan-scale public services is shaped as much by organisational design as by technology itself, with direct policy implications for cities seeking to adopt or transfer digital waste logistics strategies.

The article proceeds as follows: the literature review sets out the theoretical foundations; the methodology section describes data sources and analytical procedures; the results and discussions section presents the findings and their policy implications; and the final section concludes.

2. LITERATURE REVIEW

This study conceptualises digital waste logistics as a governance-dependent process whose outcomes may vary with organisational centralisation, decision-making hierarchies, and modes of operational control. One strand of sociotechnical scholarship suggests that digital technologies tend to become embedded in and reproduce existing institutional arrangements (Orlikowski 2007; Fountain 2001). In contrast, technology-centred and digital-transformation perspectives emphasise their capacity to reconfigure organisational processes, redistribute information, and enable new forms of operational

coordination (Mergel, Edelmann, & Haug 2019; Kitchin 2014). Rather than assuming either outcome, this study treats reinforcement and transformation as competing empirical possibilities whose manifestation depends on governance context.

Large metropolitan areas occupy a distinctive position in this debate (Hodson & Marvin 2010). As urban areas grow, the number of actors, the distances over which coordination must occur, and the heterogeneity of demand all increase, raising what transaction cost theory terms the costs of coordination (Williamson 1985; Pierre 2011). In waste logistics, this produces compounding interdependencies between collection schedules, transfer station capacity, fleet routing, and disposal throughput that cannot be managed through localised adjustment alone; the governance response tends toward hierarchy and centralisation, and digital tools enter this environment as instruments that must be integrated into pre-existing coordination structures. The critical theoretical question is therefore how digital tools function when embedded in governance architectures marked by high coordination complexity, multiple decision layers, and strong pressures toward centralised control.

2.1. *Digital monitoring, surveillance and labour*

A further dimension concerns the labour implications of digital monitoring in urban service provision. GPS-based vehicle tracking, real-time dashboards and other forms of digitally mediated operational visibility are not only technical instruments for improving coordination; they may also reshape informational asymmetries between management and frontline workers. Research on electronic performance monitoring and digital workplace surveillance shows that monitoring technologies can extend managerial visibility and control while raising questions concerning worker autonomy, stress, discretion and the distribution of power in the workplace (Aloisi & De Stefano 2022; Ravid et al. 2023). In waste logistics, this perspective is particularly relevant because vehicle-level data can simultaneously support system coordination and make frontline activities increasingly visible to higher organisational levels. The governance effects of digitalisation should therefore be assessed not only in terms of operational efficiency, but also in terms of who produces, accesses and acts upon digital information. The present study does not examine workers' subjective experiences of monitoring; rather, this literature provides a critical lens for considering how the organisational distribution of digital information may privilege managerial oversight over frontline discretion.

2.2. *Informal waste sector and waste pickers*

Finally, an institution-centred analysis of metropolitan waste logistics must recognise that formal municipal systems do not encompass the full range of actors involved in urban waste governance. Research on waste management in developing and rapidly urbanising contexts has demonstrated the significant

contribution of informal recycling and waste-picking activities to material recovery and urban livelihoods (Wilson, Velis, & Cheeseman 2006). This issue is directly relevant to Turkey, where informal recycling has developed as both a livelihood strategy and a form of labour outside formal municipal waste-management structures (Dinler 2016). Recent research focusing specifically on Istanbul further demonstrates the continuing presence and significance of waste pickers within the city's urban sustainability and recycling landscape (Geçkili Karaman & Şalgamcıoğlu 2025). An analysis centred on İSTAÇ therefore captures the formal metropolitan logistics architecture but cannot be assumed to represent the entire urban waste economy. Informal waste workers and other actors operating outside the formal organisational hierarchy may interact with waste streams through practices and institutional relationships that are only partially visible in official municipal reporting. Their limited visibility in the documentary sources used here is consequently treated as an analytical boundary rather than as evidence of their absence or insignificance. Recognising this boundary prevents the governance structure of İSTAÇ from being conflated with the broader ecology of waste governance and identifies informal-sector integration as an important area for future fieldwork-based research.

2.3. *Global South, policy mobility and Istanbul's institutional context*

The Istanbul case should be situated within broader debates on Southern urbanism and the contextual nature of urban policy transfer. Scholarship on policy mobility warns against assuming that governance models and technological solutions developed in specific institutional contexts are universally applicable, as policies circulate and are reconfigured through the political, organizational, and socio-spatial conditions of recipient cities (McCann 2011; McCann & Ward 2013; Robinson 2015). Istanbul is particularly significant in this regard. Its waste management system combines a large metropolitan scale with a multi-level governance structure, where metropolitan and district municipalities operate alongside municipally owned enterprises responsible for major service functions. Consequently, digital waste technologies enter an established configuration of metropolitan authority, organizational capacity, and public-service provision, rather than an institutionally neutral environment. Research on urban policy transfer in Istanbul further demonstrates that institutional conditions can substantially influence how externally circulating policy models are interpreted and implemented (Canitez, 2020). From a Southern urbanism perspective, this underscores the need to avoid viewing Istanbul merely as a scaled-up version of municipalities from which digital-management models may originate. Instead, the city offers a context in which the interplay among metropolitan scale, institutional arrangements, and technological adoption can be examined explicitly. Therefore, policy transfer in digital waste logistics should be conceptualized as contextual adaptation rather than direct replication. Technologies such as monitoring platforms, adaptive routing,

and data-driven decision systems may assume different functions depending on the distribution of authority, organizational capacity, and existing modes of service coordination.

Taken together, these strands of literature reveal an important gap. Existing research has generated substantial insights into digital urban technologies, institutional governance, workplace monitoring, informal waste economies, and the contextual mobility of urban policies. Still, these debates have largely developed in parallel. Less attention has been paid to how metropolitan governance structures condition the organizational function of digital technologies within waste logistics, particularly in large, centralized urban systems where formal authority, operational coordination, and digital information flows intersect. Moreover, the literature offers competing expectations: digital technologies may reconfigure organizational relationships and enable decentralized adaptation, but they may also strengthen existing hierarchies by increasing managerial visibility and coordination capacity. This study addresses this gap by examining these alternatives empirically in Istanbul's metropolitan waste system and identifying the governance conditions under which digitalization operates primarily as institutional reinforcement rather than organizational transformation.

Against this contextual background, Istanbul represents an analytically revealing case for examining how metropolitan scale, institutional arrangements, and digital technologies interact within a highly centralised waste governance architecture.

3. RESEARCH METHODOLOGY

3.1. *Data sources*

This study draws exclusively on publicly available sustainability and operational reports produced by İSTAÇ, the metropolitan company responsible for waste collection, transport, transfer, and treatment in Istanbul. These annual reports make system-level information available on organisational structure, fleet composition, waste volumes, transfer station operations, and digital management systems, and serve as the primary empirical basis for the analysis.

The data extracted from these reports cover several interrelated domains, ranging from organisational structure and governance documentation to fleet composition, waste volumes handled, transport infrastructure, digitalisation features, decision-making processes, and aggregate operational performance indicators.

Importantly, the study uses these data for governance interpretation rather than performance evaluation or benchmarking. Table 1 summarises the data domains extracted from the report corpus and their analytical use.

TABLE 1 - DATA DOMAINS EXTRACTED FROM İSTAÇ SUSTAINABILITY AND OPERATIONAL REPORTS

Data Domain	Content	Analytical Use
Organisational structure	Hierarchical governance model, operational divisions, management layers	Governance structure analysis
Fleet characteristics	Fleet size, vehicle types, aggregated capacity by waste category	Operational scale and control
Waste volumes handled	Total collected and transported waste (tons/year) by category	System output and scale indicators
Transport infrastructure	Transfer stations, treatment facilities, spatial coverage	Spatial organisation and coordination
Digitalisation features	Fleet monitoring, management dashboards, system-wide reporting	Role of digital tools in governance
Decision-making processes	Approval flows, coordination steps, operational authority	Decision hierarchy mapping
Operational performance indicators	Aggregate transport and system performance figures	Indicator-based interpretation

Source: own elaboration based on İSTAÇ sustainability and operational reports (2020–2023)

3.2. Derived operational indicators

In addition to qualitative content, the data allow for the construction of simple operational ratios used to support governance interpretation. These include waste handled per vehicle (total annual waste tonnage divided by total fleet size), transport intensity (total distance travelled divided by total waste transported, where distance data are available), monitoring frequency (characterised qualitatively from report descriptions as periodic or continuous), and the number of organisational decision layers involved in routine operations (coded from organisational charts and operational narratives).

Their purpose is to contextualise governance-related patterns rather than to benchmark efficiency. The use of such indicators is consistent with established approaches in urban waste management research, where aggregate operational metrics support qualitative interpretation rather than statistical comparison (Wilson et al. 2012; Marshall & Farahbakhsh 2013).

3.3. Analytical approach

The study adopts a single case research design, using Istanbul's metropolitan waste management system as an analytically bounded case. Single case designs are appropriate when the case represents an extreme, critical, or revelatory instance of the phenomenon under study (Yin 2018). Istanbul qualifies on all three grounds through its exceptional metropolitan scale, its highly centralised governance structure, and its unusually detailed public documentation.

The methodological framework is grounded in urban governance and public management literature, which emphasises the role of organisational design, institutional capacity, and scale in shaping policy implementation outcomes. Digital technologies are treated as governance-embedded instruments rather

than neutral technical tools, consistent with a sociotechnical perspective on organisational change (Orlikowski 2007; Fountain 2001).

3.4. Analytical framework

The analysis employs a three-dimensional framework distinguishing governance structure, decision-making mode, and operational control. These dimensions provide a consistent lens for examining how digital tools interact with the organisational arrangements of a metropolitan-scale public utility; Table 2 presents the framework, its indicators, and data sources.

TABLE 2 - ANALYTICAL FRAMEWORK FOR EXAMINING GOVERNANCE AND DIGITAL INTEGRATION IN METROPOLITAN WASTE LOGISTICS

Dimension	Indicators	Data Sources
Governance structure	Organisational hierarchy; number of management layers; centralisation of planning authority	Organisational charts; sustainability reports
Decision-making mode	Approval processes; operational discretion; role of data in routine decisions	Operational narratives; process descriptions
Operational control	Monitoring frequency; aggregation vs. real-time adjustment; reporting orientation	Fleet management descriptions; digital system documentation

Source: own elaboration

Importantly, institutional reinforcement was treated as an empirical proposition rather than a predetermined outcome. The analysis therefore searched for evidence of both reinforcement and transformation. Reinforcement was operationalised as the persistence of centralised decision authority, upward-oriented information flows, standardised operational protocols, and managerial rather than frontline use of digital information. Conversely, evidence of transformation would include redistribution of decision authority toward district or frontline units, data-enabled operational discretion, shortening or bypassing of established approval chains, real-time adaptive routing at the operational level, or the emergence of new coordination arrangements attributable to digitalisation. Evidence contradicting the reinforcement expectation was retained during coding rather than excluded. This distinction provided the basis for assessing whether digital tools reproduced or altered the existing governance architecture.

3.5. Qualitative content analysis

The primary analytical method is qualitative content analysis of İSTAÇ's sustainability and operational reports. The document corpus comprises four annual activity reports (Faaliyet Raporları) covering the period 2020–2023, together with the corresponding sustainability reports published for the same years, yielding a total of eight primary documents and approximately 740 analysed pages. All documents were accessed in their publicly available digital form from the İSTAÇ corporate website and the Istanbul Metropolitan Municipality open-data portal. The study period spans the post-2019 governance transition

at İSTAÇ and captures four consecutive annual cycles, enabling comparative reading across report cycles.

Textual and tabular materials are systematically reviewed to identify how digital technologies are positioned within governance structures and operational routines, focusing on three thematic categories derived from the analytical framework set out in the Analytical framework section above: organisational centralisation, the role of digitalisation in decision-making, and the operational flexibility enabled or constrained by digital tools. Coding proceeds inductively in two stages: relevant passages were first identified and extracted across the eight documents, then coded against the three categories and cross-checked for consistency across report years, with discrepancies retained as analytically meaningful. Coding explicitly included negative-case analysis. Passages indicating decentralisation, increased frontline discretion, shortened approval chains, or digitally enabled reconfiguration of organisational responsibilities were coded as potential counter-evidence to the reinforcement proposition. Such observations were retained regardless of whether they were consistent with the initial theoretical expectation. In the absence of a second coder, an audit trail linked each thematic assignment to its source passage and page reference, and the coded corpus was reviewed upon completion to correct inconsistent assignments. Findings are reported interpretively, with source references allowing independent verification.

3.6. *Indicator-based interpretation*

To complement the qualitative analysis, derived operational ratios are used illustratively. Waste handled per vehicle is expressed as $WPV = W/V$, where W is total annual waste transported (tons/year) and V is total operational vehicles; transport intensity is expressed as $TI = D/W$, where D is total distance travelled (km/year). Both ratios are calculated from officially reported aggregate figures and interpreted in relation to governance structure and scale rather than as efficiency measures.

3.7. *Scope and methodological limitations*

The single case design prioritises institutional depth over generalisability; causal claims and cross-city generalisations are beyond the scope of the analysis. The study also relies on aggregate, publicly available data, which do not capture micro-level operational variation or individual decision-making behaviour. Future research could extend the analysis through primary fieldwork, longitudinal comparison, or replication across other metropolitan cases.

Because the primary sources are institutional reports produced by İSTAÇ, the analysis necessarily reflects the formal organisation's representation of digitalisation and operational governance. These documents provide limited visibility into worker experiences, informal waste economies, contested

institutional practices, and actors operating outside the formal metropolitan system. The study therefore does not infer the social effects of digital monitoring on frontline workers or the consequences of digitalisation for informal waste pickers. These constitute important directions for interview- and fieldwork-based research.

3.8. *Use of artificial intelligence tools*

Generative artificial intelligence tools were used solely for language editing and stylistic refinement of the manuscript. No AI tool was used for data collection, data analysis, interpretation of results, literature review, or generation of scientific content. All analytical decisions, results, and conclusions are the sole responsibility of the authors.

4. RESEARCH RESULTS AND DISCUSSIONS

4.1. *Governance structure and organisational centralisation*

İSTAÇ operates as a wholly owned subsidiary of the Istanbul Metropolitan Municipality, responsible for the full chain of solid waste management across one of the world's most populous urban agglomerations. Its governance model is characterised by a high degree of centralisation: strategic planning, fleet management, transfer station coordination, and system-wide reporting are concentrated within a single organisational entity that oversees operations across all districts of Istanbul.

The organisational structure reflects multiple hierarchical layers. Operational decisions—including routing adjustments, fleet deployment, and service modifications—are embedded within approval processes involving district coordination units, operational management, and central administration. This hierarchy is a structural necessity: coordinating waste collection across a city of over fifteen million inhabitants requires systematic mechanisms for prioritisation, resource allocation, and accountability.

Digital technologies are integrated within this governance structure primarily as instruments of system-wide coordination and oversight. Fleet monitoring systems provide centralised dashboards aggregating vehicle location, operational status, and route progress across the metropolitan fleet, enabling senior managers to track performance in real time, identify disruptions, and generate the data required for regulatory compliance and sustainability reporting. Digitalisation thus enhances the visibility and legibility of the system from the top of the governance hierarchy. Figure 1 illustrates the layered governance structure within which digital tools are embedded.

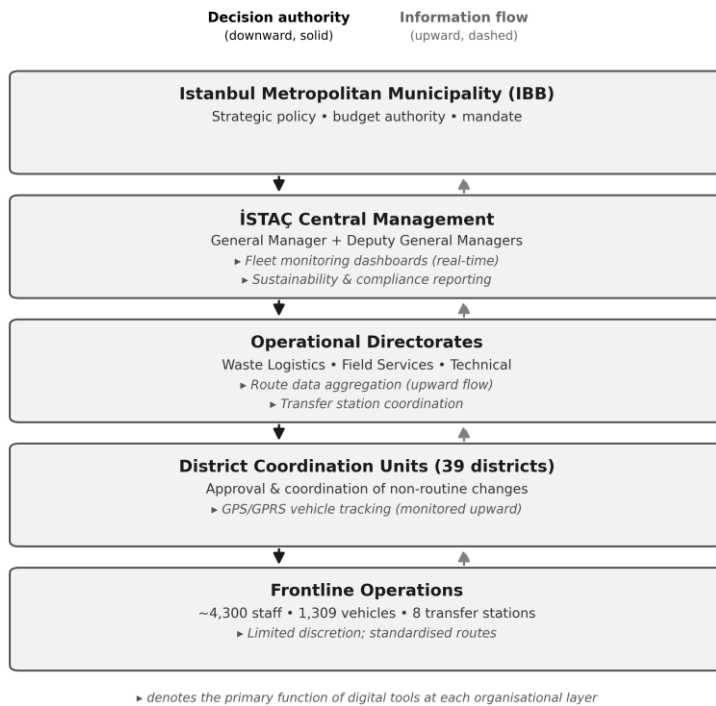


FIGURE 1 - GOVERNANCE HIERARCHY OF THE İSTAÇ METROPOLITAN WASTE MANAGEMENT SYSTEM AND THE EMBEDDING OF DIGITAL TOOLS ACROSS ORGANISATIONAL LAYERS

Source: compiled from İSTAÇ annual activity reports (2020–2023)

4.2. Decision-making hierarchies and the role of digital tools

The analysis of decision-making processes reveals that digital tools in the İSTAÇ system primarily support hierarchical coordination rather than enabling operational discretion at the frontline. Non-routine operational decisions—such as rerouting vehicles in response to service disruptions, adjusting collection frequencies in response to waste generation fluctuations, or redeploying fleet capacity across districts—typically require coordination across multiple organisational levels before implementation.

This pattern reflects the demands of metropolitan scale, where uncoordinated operational discretion risks inconsistent service provision, resource conflicts between districts, and weakened accountability. Digital tools are therefore deployed to enhance upward information flows — enabling centralised monitoring and coordination — rather than to decentralise decision-making authority to operational units.

This finding is consistent with the sociotechnical perspective that digital technologies may become embedded in and reproduce existing institutional logics (Orlikowski 2007), while providing less support in this case for transformation-oriented expectations of redistributed authority or frontline discretion. In the İSTAÇ case, digitalisation does not appear to flatten decision hierarchies; rather, it makes those

hierarchies more informationally efficient, allowing centralised authority to be exercised with greater visibility and precision.

4.3. Operational control and scale effects

The derived operational indicators summarised in Table 3 illustrate how metropolitan scale shapes the operational function of digital tools. Waste handled per vehicle reflects the aggregating effect of operating at metropolitan scale: individual vehicles handle substantial waste volumes as part of an integrated system rather than as autonomous operational units. Transport intensity could not be calculated from the available reports; nevertheless, it remains a potentially relevant indicator of the relationship between transport activity and metropolitan waste volumes.

TABLE 3 - DERIVED OPERATIONAL INDICATORS AND GOVERNANCE INTERPRETATION

Indicator	Formula	Value / Characterisation	Governance Interpretation
Waste handled per vehicle (WPV)	W / V	2020: 14,156 t/vehicle; 2021: 15,188 t/vehicle; 2022: 15,187 t/vehicle; 2023: 14,413 t/vehicle (calculated from İSTAÇ annual activity reports)	Reflects system-level aggregation and scale; individual vehicle performance subordinate to system coordination
Transport intensity (TI)	D / W	Not calculable; İSTAÇ annual activity and sustainability reports do not include vehicle-kilometres travelled as a reported operational indicator	Shaped by transfer station network and hierarchical routing logic rather than real-time optimisation
Monitoring frequency	—	Periodic / system-level; continuous dashboards for management oversight	Supports centralised visibility; primary beneficiary is senior management, not frontline operators
Decision layers	—	Multiple hierarchical approval layers for non-routine operational changes	Digitalisation enhances information flow upward; does not reduce coordination requirements

Note: Transport intensity (TI) could not be calculated, as İSTAÇ annual activity and sustainability reports do not report vehicle-kilometres travelled; future research incorporating primary operational data could address this gap. Waste handled per vehicle (WPV) figures are obtained by applying the formula $WPV = W / V$ defined in the Indicator-based interpretation section, where W is the total annual waste tonnage reported in the corresponding İSTAÇ activity report and V is the total number of operational logistics vehicles for that year (1,309 vehicles as reported for 2023; see Figure 1).

Source: own calculations based on İSTAÇ annual activity reports (2020–2023)

These indicators reveal a consistent governance pattern: digital technologies in the İSTAÇ system are oriented toward system-level aggregation, monitoring, and reporting rather than micro-level operational flexibility. Data are captured continuously at the vehicle level but aggregated and interpreted at the managerial level rather than used to enable real-time discretion by frontline staff, and the number of decision layers involved in non-routine adjustments shows that digitalisation has made the hierarchical coordination model more informationally capable without altering it. The governance structure, rather than constraining digitalisation arbitrarily, reflects the genuine coordination demands of operating at scale.

4.4. Digitalisation as institutional reinforcement

A central finding of this study is that digitalisation in the İSTAÇ system functions primarily as a mechanism of institutional reinforcement rather than transformation. Digital tools amplify the capabilities of the existing governance model—enhancing its visibility, coordination capacity, and informational efficiency—without fundamentally altering its hierarchical structure. This pattern is consistent with theoretical accounts of technology-in-practice that emphasise how digital systems tend to stabilise and reproduce existing organisational arrangements rather than disrupt them (Orlikowski 2007; Fountain 2001).

Technology-centred narratives of urban innovation often emphasise the transformative potential of digital tools, implying that adoption of the same technologies will generate comparable outcomes across cities (Kitchin 2014; Meijer, Gil-Garcia, & Bolívar 2016; Yigitcanlar, Kankanamge, & Vella 2021). The Istanbul case suggests a more cautious interpretation: in highly centralised metropolitan systems, digital technologies are governed as much as they govern, shaped by the institutional logics of the organisations within which they are deployed.

This distinction is not merely terminological. Comparative work on public sector digital transformation similarly finds that technology-induced change is contingent on governance readiness — the degree to which decision-making structures, data literacy, and coordination protocols are already aligned with the informational demands of digital systems (Mergel, Edelmann, & Haug 2019). Where such readiness is absent, digital tools are absorbed into existing workflows rather than reconfiguring them. The İSTAÇ case fits this pattern: its governance architecture was already oriented toward centralised oversight, so digital monitoring tools slotted into an existing logic rather than disrupting it. Table 4 summarises the two digitalisation modes and locates İSTAÇ within this typology.

TABLE 4 - TWO MODES OF DIGITALISATION IN METROPOLITAN PUBLIC UTILITIES: REINFORCEMENT VERSUS TRANSFORMATION

Dimension	Reinforcement mode	Transformation mode	İSTAÇ positioning
Decision authority	Remains centralised; digital tools make hierarchy more efficient	Redistributed; frontline units gain data-driven discretion	Reinforcement
Primary data beneficiary	Senior management and compliance reporting	Frontline operators and service-point adaptation	Reinforcement
Operational flexibility	Low; routing and deployment follow standardised protocols	High; real-time optimisation at vehicle or zone level	Reinforcement
Governance outcome	Institutional stability; existing logics amplified	Structural change; new coordination architectures emerge	Reinforcement

Sources: adapted from Orlikowski (2007); Mergel, Edelmann, & Haug (2019); empirical classification based on İSTAÇ annual activity reports (2020–2023)

4.5. Policy transfer and scale sensitivity

The findings highlight significant limits to policy transfer in the field of digital waste logistics. Strategies developed for smaller, more decentralised municipalities—such as real-time route optimisation and data-driven adaptive dispatching—cannot be straightforwardly replicated in metropolitan systems without accounting for the additional coordination layers and governance complexity that scale introduces. Conversely, the centralised metropolitan model exemplified by İSTAÇ may be poorly suited to contexts where smaller scale and greater operational autonomy would allow digital tools to function differently, consistent with polycentric accounts of urban service governance (Ostrom 2010).

This suggests that digital waste management policies should be scale-sensitive and governance-aware. Rather than promoting digitalisation in abstract terms, policymakers and urban managers should consider how organisational centralisation, decision authority, and operational autonomy shape the effectiveness of specific digital tools. Scaling strategies that focus solely on technology adoption, without corresponding attention to governance design, are unlikely to achieve their intended outcomes.

TABLE 5 - İSTAÇ CASE EVIDENCE, GOVERNANCE CONDITIONS, AND POLICY-TRANSFER IMPLICATIONS FOR DIGITAL WASTE LOGISTICS TOOLS

Digital tool / function	Evidence from İSTAÇ case	Governance condition identified	Policy-transfer implication
System-wide monitoring	Centralised dashboards aggregate vehicle location, status and route progress	Central managerial oversight and upward information flows	Most directly applicable where metropolitan coordination requires system-wide visibility
Adaptive routing	Non-routine routing adjustments require coordination across organisational levels	Limited frontline discretion and multi-layer approval	Transfer requires alignment between tool response time and decision authority
Compliance/reporting platforms	Digital information supports regulatory and sustainability reporting	Centralised data aggregation	Particularly relevant where reporting is consolidated across multiple operational units
Predictive/IoT applications	Limited direct case evidence	Potential usefulness depends on who can act on generated information	Requires further empirical validation before broader transfer claims

Note: Entries summarise documented patterns from the İSTAÇ case (2020–2023); governance conditions and transfer implications are interpretive syntheses and should be verified against the institutional characteristics of specific municipal contexts.

Sources: own elaboration based on İSTAÇ annual activity and sustainability reports (2020–2023)

The policy transfer problem is therefore one of assessing whether governance conditions in the receiving city are compatible with the functional logic of the tool being transferred. Real-time adaptive routing, for example, presupposes operational discretion at the vehicle or zone level, rapid approval cycles, and decentralised data access — conditions structurally absent in a system like İSTAÇ, where coordination across 39 districts requires standardised procedures and multi-layer approval. Conversely, system-wide

monitoring platforms and compliance dashboards — the tools successfully absorbed by İSTAÇ — may offer less value in smaller, decentralised systems. Table 5 translates the empirical patterns identified in the İSTAÇ case into a conditional policy-transfer framework. Rather than assigning universal levels of technological “fit” to different city types, the table links each digital function to the governance conditions observed in the case and identifies the institutional questions that should be considered before transfer to other municipal contexts.

4.6. *Institutional capacity and digital investment*

A final implication concerns sequencing. At İSTAÇ, digital tools entered a governance structure already capable of absorbing them: the preconditions for data-based oversight and centralised reporting were in place before digitalisation. Where tools precede governance reform, data may not reach decision-makers in usable form and informational requirements may raise administrative burden without improving service quality; digital investment strategies should therefore include a governance-readiness assessment alongside technical specification.

4.7. *Contributions to urban governance research*

Beyond waste management, the findings show how scale mediates the technology–governance relationship: operational metrics acquire meaning only within specific institutional contexts, challenging technology-centred narratives of urban innovation. Methodologically, the study demonstrates that single case analysis of publicly available reports can generate theoretically meaningful insights about governance–digitalisation interactions without primary operational data — an approach valuable where administrative data are limited.

5. CONCLUSIONS

This study examined how urban scale and governance structure condition the operational effects of digital waste logistics technologies, using Istanbul's metropolitan waste management system as an in-depth single case. In this highly centralised model, digital tools primarily reinforce existing hierarchical coordination arrangements, enhancing system-wide visibility, monitoring, and reporting without altering the decision-making structures within which they are embedded. This is not an implementation failure. In the Istanbul case, this pattern appears closely associated with the coordination demands generated by metropolitan scale and the existing institutional architecture, and digital technologies make these processes more informationally efficient rather than more flexible — supporting a governance-dependent understanding of digitalisation in public services.

For metropolitan municipalities, three practical lessons follow. First, municipalities operating integrated, multi-district waste systems should evaluate digital tools primarily by their contribution to system-wide

coordination — fleet monitoring, cross-district data aggregation, and compliance reporting — rather than by the promise of frontline flexibility. Second, tools designed for decentralised operation, such as real-time adaptive routing, should be adopted only after decision authority, approval cycles, and data access have been adjusted to support them. Third, pilot applications should be tested in a few districts before system-wide rollout, so that coordination effects become visible before large-scale resources are committed.

In terms of digital investment priorities, the Istanbul case suggests a clear sequencing for large centralised systems: consolidate vehicle tracking and data infrastructure first; build management dashboards and automated compliance reporting on that foundation; and only then consider predictive or adaptive applications. Budgets should pair every major technology item with a matching organisational investment — staff training, data literacy, and revised operating procedures — since tools without these complements are absorbed into existing routines without improving them.

Finally, before committing to a digital waste logistics investment, urban managers can apply a simple governance-readiness checklist derived from this study: (i) is decision authority located at the level where the tool generates data; (ii) do approval processes allow action within the tool's response time; (iii) do frontline and district units have the training and mandate to use the information produced; and (iv) is there an organisational unit responsible for translating monitoring data into operational decisions? Negative answers indicate that governance reform should precede, not follow, the technology purchase. Future research could extend this approach by comparing multiple metropolitan cases, examining how governance reforms interact with digitalisation over time, or investigating the perspectives of frontline operational staff within hierarchical waste management systems.

ACKNOWLEDGMENT

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

- Aloisi, A., & De Stefano, V. (2022). Essential jobs, remote work and digital surveillance: Addressing the COVID-19 pandemic panopticon. *International Labour Review*, 161(2), 289–314. <https://doi.org/10.1111/ilr.12219>
- Bulkeley, H., & Betsill, M. M. (2005). Rethinking sustainable cities: Multilevel governance and the 'urban' politics of climate change. *Environmental Politics*, 14(1), 42–63. <https://doi.org/10.1080/0964401042000310178>
- Bulkeley, H., Castán Broto, V., & Edwards, G. (2015). *An Urban Politics of Climate Change: Experimentation and the Governing of Sociotechnical Transitions*. Routledge.

- Canitez, F. (2020). Transferring sustainable urban mobility policies: An institutional perspective. *Transport Policy*, 90, 1–12. <https://doi.org/10.1016/j.tranpol.2020.02.005>
- Dinler, D. Ş. (2016). New forms of wage labour and struggle in the informal sector: The case of waste pickers in Turkey. *Third World Quarterly*, 37(10), 1834–1854. <https://doi.org/10.1080/01436597.2016.1175934>
- European Commission. (2018). Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. *Official Journal of the European Union*, L150, 109–140.
- Fountain, J. E. (2001). *Building the Virtual State: Information Technology and Institutional Change*. Brookings Institution Press.
- Geçkili Karaman, P., & Şalgamcıoğlu, M. E. (2025). Hidden actors of urban sustainability: Waste pickers in Istanbul. *Sustainability*, 17(14), 6236. <https://doi.org/10.3390/su17146236>
- Hodson, M., & Marvin, S. (2010). Can cities shape socio-technical transitions and how would we know if they were? *Research Policy*, 39(4), 477–485. <https://doi.org/10.1016/j.respol.2010.01.020>
- Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal*, 79(1), 1–14. <https://doi.org/10.1007/s10708-013-9516-8>
- Marshall, R. E., & Farahbakhsh, K. (2013). Systems approach to integrated solid waste management in developing cities. *Waste Management*, 33(4), 988–1003. <https://doi.org/10.1016/j.wasman.2012.12.023>
- McCann, E. (2011). Urban policy mobilities and global circuits of knowledge: Toward a research agenda. *Annals of the Association of American Geographers*, 101(1), 107–130. <https://doi.org/10.1080/00045608.2010.520219>
- McCann, E., & Ward, K. (2013). A multi-disciplinary approach to policy transfer research: Geographies, assemblages, mobilities and mutations. *Policy Studies*, 34(1), 2–18. <https://doi.org/10.1080/01442872.2012.748563>
- McKinnon, A., Browne, M., Whiteing, A., & Piecyk, M. (Eds.). (2015). *Green Logistics: Improving the Environmental Sustainability of Logistics* (3rd ed.). Kogan Page.
- Meijer, A., Gil-Garcia, J. R., & Bolívar, M. P. R. (2016). Smart city research: Contextual conditions, governance models, and public value assessment. *Social Science Computer Review*, 34(6), 647–656. <https://doi.org/10.1177/0894439315618890>
- Mergel, I., Edelmann, N., & Haug, N. (2019). Defining digital transformation: Results from expert interviews. *Government Information Quarterly*, 36(4), 101385. <https://doi.org/10.1016/j.giq.2019.06.002>
- Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies*, 28(9), 1435–1448. <https://doi.org/10.1177/0170840607081138>
- Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, 20(4), 550–557. <https://doi.org/10.1016/j.gloenvcha.2010.07.004>
- Pierre, J. (2011). *The Politics of Urban Governance*. Palgrave Macmillan.
- Ravid, D. M., White, J. C., Tomczak, D. L., Miles, A. F., & Behrend, T. S. (2023). A meta-analysis of the effects of electronic performance monitoring on work outcomes. *Personnel Psychology*, 76(1), 5–40. <https://doi.org/10.1111/peps.12514>

- Robinson, J. (2015). 'Arriving At' urban policies: The topological spaces of urban policy mobility. *International Journal of Urban and Regional Research*, 39(4), 831–834. <https://doi.org/10.1111/1468-2427.12255>
- Williamson, O. E. (1985). *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. Free Press.
- Wilson, D. C., Rodic, L., Scheinberg, A., Velis, C., & Alabaster, G. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research*, 30(3), 237–254. <https://doi.org/10.1177/0734242X12437569>
- Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International*, 30(4), 797–808. <https://doi.org/10.1016/j.habitatint.2005.09.005>
- Yigitcanlar, T., Kankanamge, N., & Vella, K. (2021). How are smart city concepts and technologies perceived and utilized? A systematic geo-Twitter analysis of smart cities in Australia. *Journal of Urban Technology*, 28(1–2), 135–154. <https://doi.org/10.1080/10630732.2020.1753483>
- Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). SAGE Publications.