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From Bureaucratic Compression to Algorithmic Holism: Data Science and AI in the Structuration of Third-Wave Digital-Era Governance

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Abstract **Review Article**

This paper is dedicated to reflection of the conception of Digital Era Governance (DEG) on the basis of recent developments of data-based technologies, such data science techniques and artificial intelligence (DSAI in this paper). It singles out four key macro-themes, in the light of which digital transformations are possible to be analyzed on the basis of such technologies. On the one hand the capability to stash and process tremendous masses of digital information removes any necessity at data compression (a trait of conventional Weberian bureaucracies). This allows decompression of data in information systems that are rich in data and it increases the potential of the public agencies as well as the civil society. Second, increasing capabilities of robotic machines have expanded the scope of work that machines can perform, superseding or extending human work, which holds important implications of restructuring the state organizations. Third, DSAI technologies can give possibilities to divide state functions in a manner, which can increase organization productivity. Such is seen in the so-called intelligent center, devolved delivery version of vertical policy regions. Fourth, in every level of government, DSAI technologies create potentialities of an administrative holism the lateral division of power and functions between organizations through government interpenetration, shared capabilities, and needs-related coordination of services. Taken together, the four themes mark a third sweep of transitions in DEG, indicating critical administrative choices that must be determined about information systems, state organization, functional tasks and outsourcing options. Moreover, they report an agenda of the extreme research interest to the sphere of a public administration which will demand profound examination and deep research.

Keywords: administrative organization and structures, governance, new public management, policy- making and public management, artificial intelligence, data science.

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1. The Digital Era Governance Model: A Conceptual Review

Within the broad landscape of digital government scholarship, a multiplicity of theoretical models and conceptual frameworks has emerged, each responding to successive waves of technological innovation and institutional adaptation. Early foundational work, such as Fountain's (2004) conceptualization of the *Virtual State*, highlighted the interplay between institutional structures and information technologies. This laid the groundwork for subsequent explorations into collaborative governance (Gil-Garcia, 2007; 2018), agile government practices (Mergel, 2016; Mergel *et al.,* 2021), and the principles underpinning open government (Ingrams *et al.,* 2020; Clarke & Margetts, 2014; Clarke, 2019). These diverse

scholarly trajectories were often catalyzed by major digital inflection points—including the rise of social media in the mid-2000s (Mergel, 2013; Mergel & Bretschneider, 2013; Criado *et al.,* 2013)—and more recently, the proliferation of data-intensive technologies.

The advent of advanced data-driven technologies has fueled a growing body of literature on *algorithmic governance*, a term that encapsulates both the opportunities and governance challenges posed by artificial intelligence (AI), machine learning (ML), and data science in public administration contexts (Rajii *et al.,* 2022; Vogl *et al.,* 2019; Meijer *et al.,* 2020). However, much of this literature remains fragmented, with substantial contributions scattered across legal studies, computational sciences, and information technology domains (e.g., Engin & Treleaven, 2019). Concurrently, new lines of inquiry have emerged around bureaucratic innovation (Kattel *et al.,* 2022) and the adaptive capacity of public institutions, particularly under the stress-test conditions of the COVID-19 pandemic (Mazzucato & Kattel, 2020).

Despite the proliferation of such studies and increasing enthusiasm for technological transformation, the public sector's progress in digital governance continues to trail developments in the private sector. Empirical audits reinforce this disparity. The 2023 UK National Audit Office (NAO) offered a critical appraisal of 25 years of digital government, highlighting the persistence of outdated IT systems and legacy data infrastructure as systemic bottlenecks impeding modernization and service innovation (NAO, 2023). Reflecting a broader disillusionment, Kempeneer and Heylen (2023) provocatively asked, "Virtual state, where are you?"—underscoring the perceived stagnation of digital transformation within public bureaucracies.

This disjuncture between theoretical enthusiasm and practical implementation may partly explain why digital government remains marginal in mainstream public administration scholarship. Much of the existing discourse continues to concentrate on specific technological architectures or isolated implementation phases, which appear less salient from the disciplinary perspectives grounded in political, humanistic, or organizational theory. Consequently, the cumulative fields of e-government, digital government, and algorithmic government represented a mere 4% of the publications in the top 20 journals in public policy and administration by 2021 (Dunleavy & Margetts, forthcoming). While this marks a substantial increase from the negligible levels observed during the 1990s (Margetts, 1999), it still suggests that the field is underrepresented, given its systemic importance (Pollitt, 2011).

Parallel to these developments, competing paradigms of public administration reform, notably the *Neo-Weberian State* (Torfing *et al.,* 2021), have gained currency. Yet, such frameworks often overlook or underemphasize the profound impact of digitalization across the public sector, except in a few cases such as Denmark (Bouckaert, 2023). This omission is significant, given the extent to which digital technologies have reshaped governance modalities, service delivery models, and institutional arrangements globally.

To address this lacuna, the Digital Era Governance (DEG) model offers a more comprehensive and integrative framework. Originally conceptualized by Dunleavy and colleagues (Dunleavy *et al.,* 2006a; 2006b) and further developed in subsequent work (Margetts & Dunleavy, 2013), DEG posits that digital technological changes—particularly those associated with data-intensive systems and automation—necessitate a fundamental reevaluation of the traditional Weberian bureaucratic model. It highlights three foundational elements that structure public governance in the digital age: digitalization, re-integration, and administrative holism. These pillars offer a scaffold to understand how information regimes, organizational design, and functional distribution are being reshaped by emergent technologies.

DEG theory departs from purely technocratic or deterministic readings by acknowledging the mediating roles of organizational practices, policy legacies, and political values. Yet, it does challenge frameworks that privilege humanistic or socio-political explanations alone (Roberts, 2019), offering instead a "quasi-paradigm" of digital governance. This characterization deliberately stops short of framing DEG as a full-blown paradigm, thereby allowing it to serve as a dynamic, evolving model responsive to ongoing technological and administrative transformations (Capano, 2021; Torfing *et al.,* 2021).

Recent research, including bibliometric analyses (Cho, 2023), affirms the DEG model's widespread influence, with over 5,000 citations of foundational works. Nevertheless, the authors emphasize that DEG should be understood not just as an antonym to New Public Management (NPM), but as a robust framework capable of mapping a complex array of technological, institutional, and policy dynamics. With the accelerating incorporation of AI, big data analytics, and automation into governance systems, the DEG model remains a valuable analytical lens—one that is especially salient for understanding the third wave of digital transformation unfolding across public administrations globally.

Table 1: Evolution of Conceptual Frameworks in Digital Government and Positioning of Digital Era Governance (DEG)

Framework / Model	Key Focus	Strengths	Limitations	Relevance to DEG
Virtual State (Fountain, 2004)	Interaction between institutions and information technologies	Institutional lens; focuses on technology-organizational co-evolution	Limited adaptation to post-2010 AI and big data advancements	Provided an early foundation for DEG's integration of institutional and digital change
Collaborative Government	Cross-agency and cross-sector collaboration in digital environments	Emphasizes interorganizational governance; relational accountability	Often lacks mechanisms to deal with data integration or automation	DEG absorbs collaboration into its "holism" pillar
Agile Government (Mergel *et al.,* 2021)	Adaptive, iterative, user-centric digital innovation in public administration	Speed, responsiveness, user feedback loops	May underplay structural and institutional inertia	Complements DEG's focus on digitalization by offering implementation strategies
Open Government (Clarke & Margetts, 2014)	Transparency, citizen participation, and open data	Normatively rich; fosters public trust and civic engagement	Often lacks integration with backend digital systems and automation	DEG incorporates open data principles into state–society information regimes
Algorithmic Governance (Vogl *et al.,* 2019)	Use of algorithms, AI, and ML in decision-making and public service delivery	Highly relevant to current data-intensive digital environments	Fragmented across disciplines (e.g., law, IT), often lacks institutional grounding	Central to DEG's third wave—enabling data decompression, robotic state, and ICDD architectures
Neo-Weberian State (Torfing *et al.,* 2021)	Legal-rational authority with modern managerial practices	Recognizes continuity of bureaucratic legitimacy	Often omits digital transformation outside certain countries	DEG offers a counter-narrative by embedding digital disruption directly into state design
Digital Era Governance (DEG)	Digitalization, functional reintegration, and administrative holism	Multi-dimensional; combines technology, organization, and policy; avoids techno-determinism	Needs further empirical testing across diverse contexts; under-represented in mainstream literature	A quasi-paradigm capturing evolving socio-technical transformations in governance

The Digital Era Governance (DEG) model has increasingly been recognized as one of the prominent frameworks shaping the discourse on public governance reform. Torfing et al. (2021) have characterized DEG as a key 'paradigm' within the field, placing it on par with the influential models of New Public Management (NPM) and the Neo-Weberian State. This elevated status is supported by the widespread academic adoption of the model: foundational publications by Dunleavy *et al.,* (2006a, 2006b) outlining the first and second waves of DEG have garnered over 5,000 citations, reflecting their centrality in administrative scholarship.

Nevertheless, the originators of the DEG model have consciously refrained from labeling it a full-fledged paradigm. Instead, they refer to DEG as a "quasi-paradigm," emphasizing its nature as a macro-model rather than a paradigmatic revolution in the Kuhnian sense (Margetts & Dunleavy, 2013: pp. 1–2). This terminological caution acknowledges the evolving, multifaceted character of DEG and its responsiveness to emerging socio-technical transformations—especially the growing impact of data science and artificial intelligence (Capano, 2021). The current agenda, therefore, is to expand and refine the DEG framework in light of the latest AI-driven innovations and organizational responses.

The updated DEG model, summarized in Table 1 of the original article, identifies three foundational elements that structure digital change in public administration: digitalization (Column A), vertical reintegration of functions (Column B), and horizontal administrative holism (Column C). Each of these dimensions captures different, yet interdependent, consequences of technological shifts for the design and

operation of the modern state. Importantly, while DEG incorporates the structural and procedural implications of digital transformation, it resists technological determinism. Rather than assuming a one-way causality from technological innovation to organizational change, DEG remains attentive to how technologies interact with institutional, political, and societal contexts (Erkkilä, 2021).

The model draws conceptual support from a spectrum of social science theories that emphasize the mutual constitution of technology and society. These range from the socio-technical systems (STS) perspective—which views technological change as bounded and mediated by human agency—to the more actor-centered perspectives such as Actor-Network Theory (ANT), which considers technological artifacts themselves as active participants in institutional change (Cresswell *et al.,* 2010). DEG is deliberately agnostic on which of these lenses best explains particular transitions but incorporates their shared insight: that digitalization is powerful, multifaceted, and institutionally embedded.

The first foundational pillar of DEG—digitalization—refers to the long-term shift from analogue to digital forms of information storage, retrieval, and processing. This transition has enabled dramatic gains in data availability, storage, and analytical capacity, leading to both enabling and constraining effects for public organizations. These include improvements in service delivery, evidence-based policy formulation, and automation, but also challenges around data governance, legacy systems, and digital equity.

The second component—vertical reintegration—addresses the evolving distribution of responsibilities within the state. Digital transformations have altered the vertical allocation of functions between central and lower-tier government bodies. Previously outsourced or siloed functions are being re-centralized under 'intelligent centres,' especially where scale economies and data consolidation can enhance productivity and oversight. Conversely, citizen-facing service delivery functions are increasingly devolved to regional or local units better equipped to provide tailored interventions—marking a shift toward Intelligent Centre/Devolved Delivery (ICDD) models.

The third and final component—horizontal administrative holism—describes how technology reshapes inter-organizational relationships across policy sectors and regulatory domains. As service delivery and regulation become increasingly data-intensive, public agencies must overcome siloed structures by pooling data science and AI expertise. This shift is particularly evident in the need for integrated responses to complex governance challenges, such as algorithmic regulation of digital marketplaces or real-time service coordination among social service providers (Knox, 2019).

These three components have not emerged simultaneously but have evolved across three successive waves of DEG development. The first wave, DEG1, introduced the model primarily as a counterpoint to NPM, challenging its emphasis on fragmentation, competition, and outsourcing. In its initial articulation, DEG1 was often interpreted narrowly as an antonym to NPM, although the authors had developed a more nuanced argument in their accompanying monograph (Dunleavy *et al.,* 2006a). Cho's (2023) bibliometric analysis underscores this misreading, highlighting how early receptions focused more on DEG's critique of NPM than on its constructive framework.

The second wave, DEG2, emerged in the wake of the 2008 global financial crisis. Under conditions of fiscal austerity, governments were compelled to pursue cost-saving measures that simultaneously accelerated digitalization and reversed previous outsourcing trends. This period witnessed the rise of "digital by default" strategies and the re-governmentalization of digital capacities. Pioneering institutions such as the UK Government Digital Service and Australia's Digital Transformation Agency spearheaded efforts to consolidate IT infrastructure, expand in-house expertise, and modernize legacy systems (Clarke, 2017, 2020; Margetts & Dunleavy, 2013; Dunleavy & Margetts, 2015).

The third wave, or DEG3, currently underway, reflects more sophisticated and systemic transformations driven by data science and artificial intelligence (DSAI). DEG3 expands the scope of digitalization from administrative efficiency to intelligent automation and predictive governance. Within Column A of the model, DEG3 introduces the notion of a robotic state, wherein automated systems interact with the physical world to perform regulatory, operational, or service tasks traditionally handled by humans. This includes biometric border control, AI-driven policy simulations, and robotic devices in healthcare and defense.

In Column B, DEG3 intensifies pressures toward ICDD architectures, centralizing data analytics and machine learning expertise while decentralizing physical service provision. This dual shift allows states to optimize resource allocation, standardize performance metrics, and ensure responsiveness at the point of delivery. However, it also raises concerns around algorithmic bias, transparency, and control over "intelligent centres."

Column C captures the growing importance of regulatory holism, as digital platforms and AI-powered services defy traditional sectoral boundaries. The integration of horizontal DSAI capabilities—such as

algorithm auditing, bias detection, and real-time supervision—has become essential to maintaining regulatory coherence and legitimacy. This transformation builds on earlier notions of "needs-based" service integration but extends holism into all facets of regulation and governance, across tiers and domains.While DEG3 introduces novel capabilities and organizational imperatives, it remains deeply grounded in the theoretical and practical insights of the first two waves. The continuity across waves ensures that DEG functions as a cumulative and adaptive quasi-paradigm—one that aligns with the incremental, recursive nature of public sector innovation. As such, the DEG model provides a robust framework for understanding the enduring and emergent dynamics of public administration in the digital age.

2. Data-Intensive Information Regimes and the Evolution of Digital Decompression

Historically, public sector agencies have operated within information environments characterized by pre-structured, highly compressed data regimes. These compressed forms, often stored in analog filing systems, allowed for individual knowledge retrieval but generated minimal data usable for systematic policy analysis (Hood and Margetts, 2007: p. 139–140). The introduction of early digital systems—commonly referred to as legacy IT—improved batch data processing capacities but failed to overcome the fundamental limitations of compressed information architectures. Despite operating for decades (NAO, 2023; US GAO, 2016; US GAO, 2023), these legacy systems did little to enhance analytical capacities or contribute meaningfully to evidence-based policymaking (Margetts, 1999), reinforcing a traditional model in which transactional data was largely disconnected from service design or strategic governance (Alexandrova *et al.,* 2015).

Even as the proliferation of digital data sources began in the 2000s, bureaucratic systems rooted in the Weberian tradition continued to invest heavily in information compression. These systems prioritized the minimization of stored data at the point of entry—adopting 'lossy' techniques that discarded rich contextual information in favor of simplified, transaction-oriented data formats. The outcome was an information regime wherein administrative interactions were reduced to rigid, pre-fixed knowledge units, rendering subsequent reanalysis or multi-purpose utilization of the data nearly impossible.

By the 2010s, however, the technological underpinnings of government digital infrastructure had begun to evolve rapidly. Advancements in software, real-time communication, cloud-based storage, and the exponential growth of citizen-generated data via digital platforms created the conditions for a fundamental shift. These capabilities not only enhanced traditional governance mechanisms—sometimes conceptualized as "digital Weberianism" (Muellerleile and Robertson, 2018)—but also enabled the decompression of information previously stored in highly reduced formats. What had once been static and fragmented records could now be transformed into analyzable, interconnected datasets using advanced digital techniques (Dunleavy, 2022).

During the New Public Management (NPM) era, the rise of digital recordkeeping generated hybrid information systems built around metrics, KPIs, test scores, and performance targets. However, these remained bound by the same compressed logics—employing pre-structured, inflexible data formats. While such systems enhanced managerial oversight, they failed to adapt to the more dynamic, multi-dimensional data needs of the emerging digital state.

The gradual transition to *lossless* digital interactions marks a defining feature of the current era. Administrative encounters increasingly generate full-text, audio, and video records, enabled by tools such as Body Worn Video (BWV) for law enforcement or recorded interviews in welfare services. These records serve both operational and accountability purposes, forming digital archives that can be continuously re-analyzed using machine learning and natural language processing as analytical capabilities advance. For example, BWV footage triggered during arrests or searches can become a crucial evidentiary resource in cases of misconduct. As such forms of data become ubiquitous, the capacity to mine these sources retroactively and adaptively is significantly expanded.

The democratization of digital recording tools has extended these capabilities to citizens. A seminal example is the smartphone footage captured by Darnella Frazier, which exposed discrepancies in the official account of George Floyd's death and catalyzed global demands for justice (New York Times, 25 June, 2021). Routine recording of encounters with public officials—such as social workers—by citizens is increasingly common and has substantively altered professional behaviors toward transparency and accountability (Breit *et al.,* 2020).

The data revolution is not confined to state systems alone. A massive influx of data from civil society—driven by interactions with digital platforms—now constitutes a vast but selectively accessible information resource. In liberal democracies, access to this data is carefully controlled due to privacy concerns and fears of governmental overreach (Dunleavy, 2016). Nonetheless, in specific contexts such as national security or public health emergencies, selective access is permitted. During the COVID-19 pandemic, for instance, telecommunications providers and retailers shared anonymized location data with public authorities

to facilitate contact tracing. Additionally, anonymized digital footprints, such as consumer behavior or social interactions, offer actionable insights when analyzed by trusted intermediaries (Bright *et al.,* 2014).

Despite the availability of large datasets, public agencies historically lacked the technical means to extract meaningful insights, often limiting their analysis to basic metrics or KPIs. However, from the 2010s onwards, dramatic advancements in data science across major technology and logistics firms—Google, Apple, Amazon, Facebook, Microsoft, and Walmart—began to reshape these limitations. Data science evolved rapidly, incorporating enhanced statistical optimization and the development of machine learning (ML) and artificial intelligence (AI) techniques capable of processing complex data in unstructured environments.

While neither ML nor AI are inherently new—ML emerged from statistical theory and AI has roots dating back to the 1960s—recent innovations have been powered by the availability of massive datasets, expanded computational resources, and widespread internet connectivity. Collectively known as data science and artificial intelligence (DSAI), these technologies "learn" from large-scale data, detect patterns, and refine predictive models over time, unlike traditional rule-based programming. DSAI systems are now used extensively in the public sector for classification, prediction, simulation, and personalization tasks (Margetts and Dorobantu, 2019, 2022; Margetts, 2022). They are applied in areas such as online harm detection, tax fraud monitoring (Engstrom *et al.,* 2020), and early warning systems for public service failure.

One notable application is the development of risk models for decision-making in individual cases. The COMPAS algorithm, for example, is used across several jurisdictions in the United States to assess the likelihood of reoffending and influence bail or parole decisions—though it has been subject to significant controversy (Young, 2018; Završnik, 2019). In the UK and the US, ML is also being applied to identify children at risk within social welfare systems (Leslie, 2020).

Another promising frontier lies in agent-based modeling, where data from individual units—such as citizens, firms, or institutions—can be synthesized into dynamic simulations of entire economic or social systems. These models are increasingly used in policy design and emergency planning, such as in pandemic preparedness or resource allocation modeling (Axtell, 2018; Guerrero and Castañeda, 2021). Their technocratic utility depends, however, on the ability of public administrations to shield expert decision-making from excessive political interference (Esmark, 2017). The mixed performance of UK pandemic governance, for instance, highlighted both the success of vaccine deployment and the failures associated with delayed lockdown decisions (Arbuthnot and Calvert, 2021). As DSAI becomes embedded across the public sector, its applications will encompass automated triaging of forms, biometric and photographic verification, natural language processing of feedback and complaints, and the monitoring of distributed service systems. Advanced DSAI use cases may include early detection of abnormal performance patterns in hospitals or care institutions, prediction of welfare dependency risks, and advisory tools for probation services. However, such applications necessitate large, unbiased training datasets, rigorous algorithmic transparency, and thorough ethical oversight (Leslie, 2019).

A further development reshaping the relationship between state and citizen is the diffusion of DSAI-powered technologies into consumer markets. The widespread availability of personal health monitoring tools—such as smartwatches and wearable devices—has eroded the state's traditional monopoly over high-quality health data. In a mature e-health environment, it is conceivable that AI-driven personal health systems will autonomously summon emergency services and negotiate hospital admissions in real-time, without human intermediation. While such scenarios remain aspirational in most jurisdictions, the accelerated adoption of remote consultations during the COVID-19 pandemic demonstrates that public healthcare systems can evolve rapidly when under pressure. The most recent catalyst for transformation is generative AI, particularly large language models (LLMs) such as ChatGPT, which was released publicly by OpenAI in early 2023. These tools promise to revolutionize citizen–state interaction through more responsive chatbots, intelligent avatars, and new modes of continuous consultation. For example, LLMs can facilitate "conversational consultation" by collecting brief user feedback and synthesizing it across populations to inform policy (Margetts and John, forthcoming). While still in early stages, the incorporation of LLMs into public services—especially in education and personalized engagement—appears increasingly feasible (Margetts and Dorobantu, 2019).

In sum, the transition toward data-intensive information regimes underpinned by DSAI marks a critical shift in the logic of governance. Moving beyond compressed, lossy administrative systems, governments are gradually embracing decompressed, dynamic, and re-analyzable data architectures. These developments not only expand analytical capacity and service responsiveness but also challenge public agencies to adapt institutionally, ethically, and operationally to the demands of the digital age.

3. Robotic State Development

Digitalization, the accumulation of massive data stores, real-time communications, and the advancement of data-intensive analysis and AI techniques have primarily transformed the "bits

world"—the domain of digital information and system logic. These developments, while significant, originally had only indirect implications for the physical world of "atoms." However, recent convergence among these technologies is now ushering in a shift in how digital systems interface with their environments, such that automated stimulus-response processes can bring about tangible changes in the external physical world. It is in this context that we define robotics.

Like DSAI itself, robotics is a long-established subfield of computer science that has undergone a transformation due to the availability of massive data resources. Earlier generations of robots were driven by symbolic AI—where behavior was dictated by pre-programmed code embedded into the robot. However, advancements in computer vision and AI now allow robots to interpret their surroundings and refine their behavior through data-based training. As a result, modern digitalization has positioned robotics as an increasingly central technology across sectors far beyond its historical base in manufacturing.

Robotic capabilities now present expansive opportunities for public sector automation by enabling actions in the physical world. In the second wave of DEG, robotic-like capabilities were primarily limited to "zero touch operations" located in the back office. These included systems where, for example, an online application cross-checks against multiple databases to execute fully automated actions—such as the UK's road tax renewal process, which links vehicle licensing agencies, insurance providers, and local garage databases.Moving beyond these indirect systems, robotic interfaces with the physical environment have become more prominent. Automated roadside cameras used in traffic enforcement exemplify this shift; they can autonomously trigger penalties or enforcement procedures without human intervention. With the AI enhancements that define DEG3, such robotic devices have now proliferated throughout government operations and extended into front-office environments, as illustrated in Table 2.

"Static" robots, such as biometric passport or security gates using facial recognition, have replaced manual checks at borders and secured sites. Similarly, systems that provide remote flood warnings or control water flow have enabled automated environmental management across entire river basins. In healthcare, "service robots" capable of nuanced pattern recognition are being used to assist medical professionals—for example, in cancer screening—and support near-autonomous surgical procedures. These robots also perform remote, automated cleaning tasks in operating theatres and clinical facilities. Hospitals, prisons, and defense bases have been early adopters of autonomous guided vehicle (AGV) systems (Gonzalez-Gonzalez, 2021; Fanti *et al.,* 2020). Although fully roboticized logistics centers like those operated by Amazon and Ocado have yet to appear in the public sector, plans for public infrastructure that accommodates separate circulation zones for humans and AGVs are being explored. In the realm of defense, robotic components have become increasingly embedded within modern equipment. This includes centrally controlled drone systems and autonomous aviation platforms, often integrated as high-cost force multipliers in aircraft, naval vessels, and other defense technologies

Table 2: Emerging Applications of Robotics in the Public Sector under DEG3

Type of Robotic System	Functionality	Sector / Use Case	Level of Interaction
Static Robots	Automated identity verification via biometric recognition	Biometric passport gates at airports; security gates at border and secure sites	Front-office (Citizen interaction)
Remote Environmental Robotics	Automated sensing and control of physical infrastructure	Remote flood warning systems; flow-control gates in water management	Infrastructure (Environment)
Service Robots (Medical/Healthcare)	Assist in diagnostics, surgical support, automated cleaning	Cancer screening assistance; robotic surgery; sterilization in operating theatres	Clinical front-line & operations
Autonomous Guided Vehicles (AGVs)	Transport, delivery, or patrol in facilities without human drivers	Hospitals, prisons, and military bases (material transport, surveillance)	Logistics / Internal mobility
Zero-Touch Operations (Back Office)	Fully automated data validation and action across networked databases	Online vehicle tax renewal; automated license checks	Back-office automation
Automated Enforcement Robots	Detection of infractions and automatic triggering of penalties	Roadside traffic enforcement via ANPR cameras	Field operations (Law enforcement)
Autonomous Military Systems	AI-enhanced control of drones, aircraft, ships, and surveillance systems	Defense platforms with centralized robotic components (e.g., drones, autonomous naval assets)	Strategic (High command and control)

Robotic Infrastructure Not Yet Realized	Integrated circulation systems for robots and humans in public buildings	Proposed fully roboticized public logistics centers (modeled on Amazon/Ocado systems)	Future infrastructure planning

At first glance, the expansion of robotic technologies in public administration may appear to reinforce centralized control. Many of the systems described earlier—such as biometric passport gates, robotic hospital devices, and military drone coordination platforms—are developed or procured centrally and tend to produce centralizing effects. A notable example occurred in the spring of 2023 when the UK Border Force's e-passport gates malfunctioned simultaneously across multiple airports, disrupting 60–80% of standard passport clearances nationwide. This incident highlighted how centralized systems can become single points of failure with system-wide implications.

Yet, historical patterns from previous waves of computerization and automation suggest a more nuanced trajectory, where technological change has often generated both centralizing (network-based) and decentralizing (database-based) effects (Bloom *et al.,* 2009). Robotic devices are no exception. They not only support central control through data integration and automated processing but also enhance decentralized operational capabilities. Mobile robotic systems—such as bomb disposal units or aerial drones—can empower frontline workers by enabling them to perform tasks that previously required support from remote or highly centralized authorities.The utility of modest, commodified robotic innovations in decentralizing functions is particularly evident in military contexts. For instance, the Ukrainian war since 2022 has demonstrated how inexpensive, commercially available drones and unmanned aerial vehicles (UAVs) can dramatically extend the surveillance and strike capacities of frontline military units. These systems operate at a fraction of the financial and logistical burden associated with traditional air force assets for reconnaissance and close-support missions (Kunertova, 2022). Both Russian and Ukrainian forces have made extensive use of hobbyist drones, often acquired through large-scale citizen-led donation initiatives—dubbed "dronations"—which have rapidly expanded UAV access (Kunertova, 2023).

Beyond military applications, robotic technologies hold potential to assist a wide range of public sector workers, including healthcare providers, social workers, and logistical personnel. For example, drones could facilitate lightweight deliveries to remote areas, and augmented load-lifting exoskeletons may reduce strain-related injuries among nurses or field technicians. The broader trend toward commodification and accessibility of robotics significantly enhances prospects for "last mile" innovations. These localized, micro-level tools could increase operational productivity across various institutional contexts, ranging from small municipal departments to large hospital systems (see also the next section). Despite these advances, the rollout of robotic technologies remains fragmented and uneven. Many current applications are relatively mundane—such as robotic entry systems or autonomous vacuum cleaners in hospitals and eldercare facilities. However, other devices raise ethical, legal, and social concerns. For instance, some photographic and biometric technologies used in facial recognition systems or medical monitoring tools have demonstrated racially biased outcomes. Devices such as home-use oximeters, which became widespread during the COVID-19 pandemic, and facial scanners in passport gates, have been shown to perform inconsistently across different skin tones (Leslie, 2020).

More controversially, a growing number of robotic applications exhibit novel and far-reaching capabilities. These include partially autonomous weapons systems, border-patrolling robotic "dogs," and audio-based systems that detect voice stress or potential misinformation during interactions with government call centers—such as those used by tax authorities. In the domain of social robotics, early experiments in countries like Japan have provided valuable but mixed lessons. Japan has led in deploying robotic assistants in educational and eldercare contexts, aiming to supplement human behavior and improve service quality. However, practical limitations remain significant. In elderly care settings, the introduction of social robots has not reduced staff workloads. Instead, they often created new burdens related to maintenance, coordination, and supervision of the robotic systems (Wright, 2023). Looking forward, the most significant shift in robotic state capabilities may arise from their integration with data-intensive information regimes and emerging technologies like large language models (LLMs). As noted in the previous section, LLMs represent a major leap in natural language understanding and machine–human communication. When paired with robotic devices, these virtual assistants will enable more seamless and adaptive interactions between systems and users. This fusion will enhance the capacity to automate complex task sequences, making public service robots not only more responsive but also more autonomous in executing coordinated actions (Vemprala *et al.,* 2023).

4. Intelligent Centre, Devolved Delivery Structures

The proliferation of data-rich digital technologies, as outlined in previous sections, offers unprecedented opportunities for innovation in public policy and service delivery. However, unlocking this potential requires substantial transformation in bureaucratic processes—transformations far more constrained in public institutions than in unified private sector organizations. A key organizational issue in this context is the persistent challenge of determining which

level of government performs which functions—a vertical "functional allocation" dilemma that has engaged scholars for decades. The depth of this issue stems not from technical limitations, but from enduring political and ideological divisions around centralization versus decentralization (Dunleavy, 2021). While purely digital functions tend to encourage centralization—especially where expert DSAI talent is scarce—labour-intensive services remain localized, relegated to lower-tier governments situated closer to citizens.

This logic significantly deviates from the prevailing scholarly frameworks used to explain state structural designs. These legacy perspectives, outlined in the four blue-shaded rows of Table 3 (see Dunleavy, 2022, section 3), include: (1) welfare economics, which advocates decentralization to optimize scale and responsiveness; (2) the liberal political economy approach (e.g., the Peterson model), which explores policy feasibility in democracies with high citizen mobility; (3) macro-financial explanations emphasizing the centralized pooling of resources necessary for modern welfare states; and (4) radical political economy arguments that posit capitalist systems concentrate high-salience economic functions at central levels while relegating less profitable or politically sensitive roles to more democratic institutions. These models all recognize that constitutional and legal structures—unique to each country—fragment or constrain the application of any single theoretical logic. As a result, functional pressures emerge more as dynamic trends than static rules, requiring continuous adaptation and institutional "work-arounds."

Digital Era Governance (DEG) introduces a fifth organizing logic, focused on optimizing productivity by aligning public sector architectures with digital technology imperatives. This can be observed most clearly in the private sector, particularly among logistics giants such as Amazon, Walmart, Ocado, and IPD. Unlike platform companies like Google or Meta, these logistics corporations interact directly with the physical world—making them more apt comparators for government operations. With the ability to restructure at will or build from scratch, these firms have successfully developed centralized, highly digitized "intelligent centres" supported by advanced optimization, machine learning, and operational research capabilities. These central hubs manage data science functions at scale while orchestrating granular "last-mile" deliveries through dense, often subcontracted, decentralized networks.

To replicate similar productivity gains, public sector institutions must rethink their data management paradigms. While new technologies enable centralization through wider spans of control, enhanced performance metrics, and real-time feedback loops, they also democratize access to expert systems at grassroots levels—thus enabling decentralization (Bloom *et al.,* 2009). These dual imperatives converge in the logic of Intelligent Centre, Devolved Delivery (ICDD) structures. Within government verticals, intelligent centres aim to develop "do it once" digital policy solutions by creating centralized data repositories (e.g., cloud-accessible data lakes), deploying highly skilled DSAI teams, and building sophisticated analytic capacities. Like corporations, these entities use data-driven insights to anticipate staffing needs, detect service delivery problems, and implement performance-based planning.

Realizing the potential of intelligent centres also requires universal digitization of citizen interfaces, internal HR systems, and staff workflows—initiatives often met with resistance from public sector unions. However, when properly implemented, these centres eliminate the slow, statistical lag associated with legacy systems (Hood and Margetts, 2007), replacing them with real-time dashboards capable of continuous system monitoring, problem recognition, and rapid adjustment. This adaptability is particularly vital in high-velocity policy fields such as public health, defense, and emergency management.

Digital capabilities now challenge the long-standing Hayekian argument against the feasibility of centralized planning in complex economies. The traditional objections included concerns about knowledge aggregation, algorithm design, computational limits, and implementation capacity (Palka, 2020). However, modern developments—especially in mid-sized states like the UK or Japan—undermine each of these points, although such scalability remains a challenge in vast federal states like the USA, China, or India. The rise of in-house DSAI and intelligent systems has rendered large-scale data integration and centralized optimization more feasible than ever before.

Parallel to these centralizing forces, modern digital technologies also reinforce decentralization. Tasks that rely on personal interactions or involve physical world services are better handled at local or regional levels. In-person delivery of public services—particularly those involving welfare, education, or healthcare—should be devolved to units closest to the populations they serve, enhancing responsiveness and productivity (Schneider, 2019). Lower-tier governments are particularly well-positioned to adapt services to the needs of more homogeneous client groups, to maintain continuity in service delivery, and to harness the learning benefits of iterative IT systems (Pournanas, 2020).

Despite challenges in attracting top DSAI talent, decentralized agencies can leverage open-source innovations and community-driven platforms to stay aligned with evolving digital standards (Von Hippel, 2006). In federated states or major metropolitan areas,

regional governments often gain a more integrated and holistic view of service needs than central agencies, which helps in deploying digital services more effectively (Dunleavy, 2021). Integrating robotics and centralized software tools at the local level enables regional agencies to enhance delivery productivity through tailored implementations, while still benefiting from centrally coordinated technological ecosystems (Dunleavy, 2021).

However, public institutions have struggled to emulate the private sector's efficiency in coordinating inter-tier collaboration. National governments have often maintained top-down control rather than supporting innovation at the local level. Constructive engagement could include:

- Providing shared technical infrastructure and open-source software;
- Conducting and disseminating nonpartisan research on digital trends;
- Developing cooperative frameworks for digital regulation and performance management.

Unfortunately, such initiatives remain rare. In federal states, vertical disagreement—often ideologically driven—has frequently derailed collaborative innovation and discouraged uptake of centrally provided technological tools. This fragmentation has undermined productivity growth, interoperability, and citizen trust in public service systems.

ICDD pressures have only recently become visible and remain constrained by long-standing constitutional and fiscal frameworks—some dating back over a century. In countries like the United States, such rigidities have contributed to delays in adopting modern digital solutions (Clarke, 2019). The COVID-19 pandemic laid bare these deficiencies, as fragmented information systems and inconsistent digital guidance exacerbated confusion among citizens. The Covid Crisis Group (2023) summarized the problem starkly: "The United States faced a twenty-first-century challenge with a system designed for nineteenth-century threats."

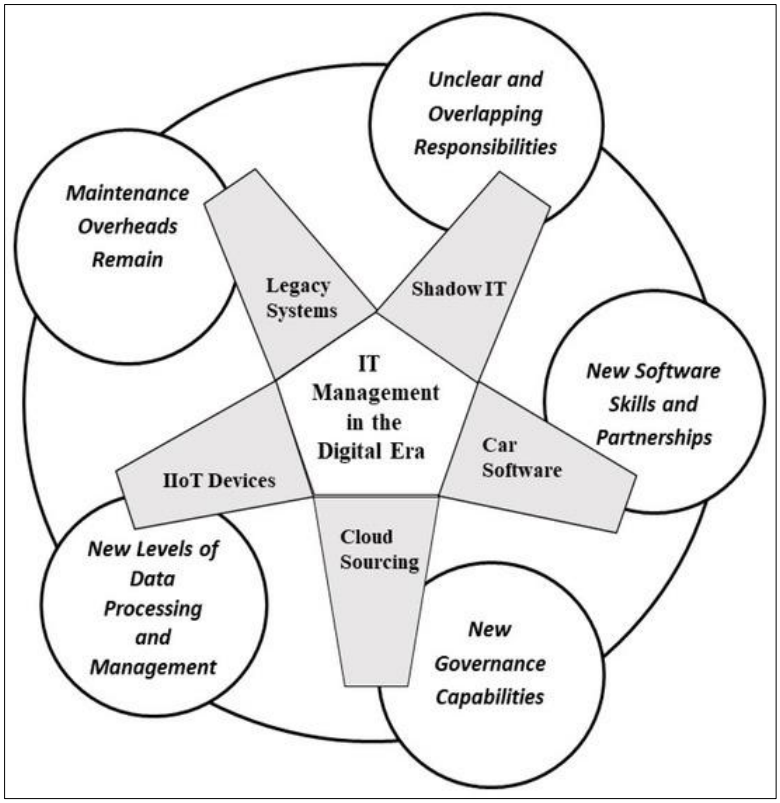

Figure 1: Structural Logics of Intelligent Centre and Devolved Delivery in Digital Era Governance

This figure illustrates the dual imperatives driving public sector transformation in the digital era: centralized "intelligent centres" leveraging DSAI for planning and monitoring, and decentralized "last-mile" service delivery agencies operating closer to citizens. It contrasts traditional theoretical logics of functional allocation with the emergent ICDD model, emphasizing how digital technologies simultaneously enable high-level optimization and localized responsiveness across state tiers.

5. Administrative Holism in the Digital Era: Integrating Horizontal Capacities Across the State

As vertical restructuring through Intelligent Centre, Devolved Delivery (ICDD) architectures

progress, an equally crucial transformation unfolds along the horizontal axis of governance—what Digital Era Governance (DEG) theory conceptualizes as administrative holism. This facet of DEG concerns the reallocation and coordination of functions across different agencies and policy sectors within the same tier of government. Digitalization enhances this integration by making it both technically feasible and functionally necessary to pool data, expertise, and decision-making logic across traditional silos.

At the national level, administrative holism is increasingly vital to overcoming fragmented regulatory capacities and addressing emerging technological demands. Scarce DSAI expertise, rapidly shifting digital markets, and the dissolution of sector-specific regulatory regimes all drive the need for centralized capabilities and shared resources. The concept of 'horizontal technologies'—data science and artificial intelligence techniques applied across multiple policy sectors—underpins this shift. As shown in the expansion of digital marketplaces, such as ride-hailing, home-sharing, financial technology, and AI-driven platforms, traditional regulatory regimes have been quickly outpaced. Firms like Uber, Airbnb, and blockchain-based services have bypassed or disrupted long-standing legal frameworks, rendering existing sectoral regulators ill-equipped (Fung and Lessig, 2023; Margetts and Dommett, 2020).

Moreover, platform companies have actively replaced public competition and anti-trust frameworks with private rule-making systems. AI adoption across consumer markets, from personalized shopping to financial scoring, poses challenges that cannot be resolved within legacy regulatory silos. Governments must now evaluate algorithmic bias, transparency, and public interest outcomes—a task requiring deep technical understanding, often far removed from the historical remit of traditional regulators (Aitken *et al.,* 2022; Ostmann and Dorobantu, 2021; Suss and Treitel, 2019).

Although some optimistic views foresee the rise of fully automated, AI-driven regulatory frameworks ('regulation by robots') (Coglianese and Lehr, 2017), past efforts to encode laws as computational systems have moved slowly. Large agencies have begun to build internal DSAI capacity, but most smaller regulators lack the scale, funding, or technical scope to do so. The solution lies in pooling expertise at the tier level—developing centralized competence hubs within the 'intelligent centre' that can serve a broad range of agencies and subnational partners (Aitken *et al.,* 2022). Cybersecurity stands out as a model of such pooling, with national agencies like the NSA, GCHQ, and the Australian Signals Directorate delivering integrated protection across the whole government system.

Beyond regulation, policy holism—enabled through technologies such as agent-based modelling, machine learning, and large-scale simulations—offers unprecedented potential for joined-up governance. These tools allow for scenario testing, outcome forecasting, and impact modelling before implementation, enabling smarter, evidence-based policy (Axtell, 2018; Margetts and Dorobantu, 2019, 2022). However, uptake is hindered by political instincts, departmental turf protection, and a reluctance to shift power toward data-driven, technocratic models.

Notable successes, such as the expanded use of epidemiological and economic modelling during the COVID-19 pandemic, show what is possible when urgency aligns stakeholders. However, missed opportunities remain: furlough schemes and stimulus packages were designed without fully integrated modelling, and lessons from those gaps have yet to be institutionalized. Even within central banks, commercial confidentiality has made distress prediction difficult, though public machine learning tools may offer workarounds (Suss and Treitel, 2019).

At the decentralized level, administrative holism evolves more slowly but with increasing relevance. In DEG2, the emphasis was on needs-based holism—where delivery agencies integrate services to address complex client needs. That logic continues under DEG3, but the scope has expanded. For instance, social regulation can benefit from real-time pooling of data across hospitals, general practitioners, police, and social care. This enables predictive, proactive safeguarding systems based on harmonized criteria, a vast improvement over inconsistent 'case conferencing' methods.

Similarly, shared access to patients' social media feeds and home-monitoring systems (e.g., fall detection or medication alerts) among family, caregivers, and professionals provides continuous visibility into vulnerable individuals' well-being. These data-driven interventions can prevent emergencies by identifying and addressing issues before they escalate.

However, administrative holism must be publicly accountable. Citizens must perceive data sharing as advancing their own welfare, not merely expanding state power. Examples of failure to meet this standard include the infamous Australian 'robodebt' program (Carney, 2018), racially biased sentencing algorithms in the US (Yong, 2018), and the flawed school exam grading system in the UK during the COVID-19 pandemic (Elbanna and Engesmo, 2020). These cases, grounded in inadequate data and poor algorithmic design, demonstrate the risks of cost-cutting shortcuts without ethical safeguards. Instead, holistic systems must be paired with rights-based governance and transparent operations. For example, Google and

Apple's COVID-19 phone tracker was effective precisely because it prioritized user privacy and anonymity, unlike the UK's failed attempt at centralized tracking (Arbuthnot and Calvert, 2021).

Critically, the expanded concept of administrative holism goes beyond just client-facing services. It also reflects state-centered imperatives—such as pooling scarce regulatory expertise and coordinating cross-sector DSAI usage. Both needs-based and state-centered holism are essential for unlocking the full potential of DEG. However, entrenched legacy practices remain a significant barrier to both.

For example, emergency services in most democracies still rely on siloed, audio-only phone systems first developed in the 1930s (British Telecom Archives, undated). Integration of ambulance, fire, and police services through video-enabled systems is technologically feasible but institutionally distant. UK failures during crises like the Manchester Arena bombing (BBC, 2021) or the Grenfell Tower fire (Grenfell Tower Inquiry, 2022) reveal the human cost of these inefficiencies. Even planned upgrades like the UK's Emergency Services Network—which seeks to enable GPS and video—have encountered major delays and design issues (National Audit Office, 2019).

Meanwhile, defence sectors have rapidly adopted digitally unified command systems due to battlefield imperatives. Civil agencies lag behind but face increasing pressure to digitize, driven by cloud computing adoption and the erosion of traditional IT outsourcing models. During COVID-19, governments learned to harness anonymized commercial data via universities and consultancies, showing the value of external integration.

Finally, the mental siloing of how public servants think about data—fixed formats, outdated statistics, and non-integrated metrics—emerges as a critical barrier to progress. True administrative holism requires not only organizational and technical change but also a reformation in institutional thinking about how information should flow, be shared, and be used to serve both state goals and individual needs.

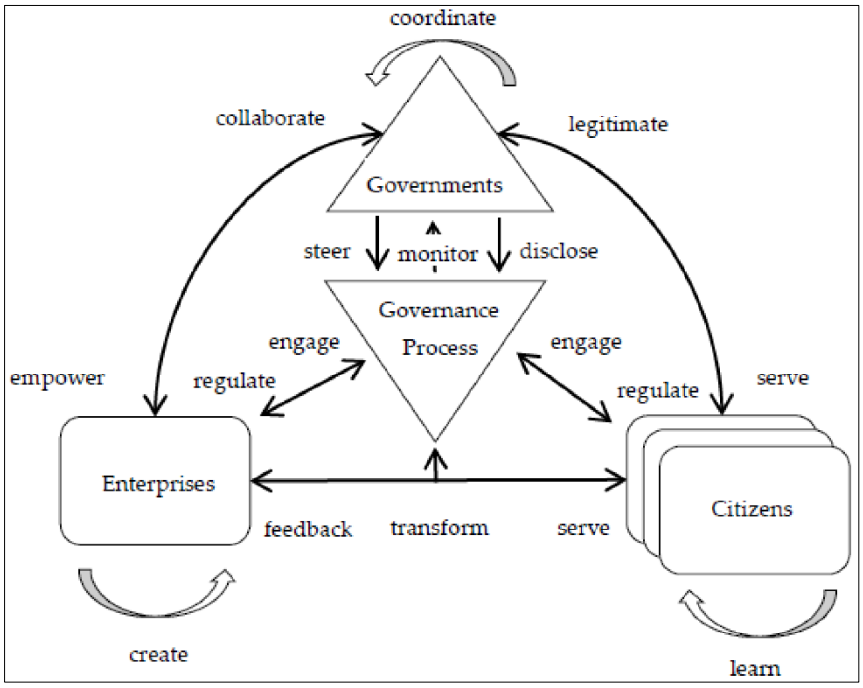

Figure 2: Multi-Stakeholder Dynamics of Administrative Holism in Digital Era Governance

This figure illustrates the complex, interactive governance ecosystem in which governments, enterprises, and citizens collaboratively engage through dynamic feedback loops. It highlights how digital-era administrative holism relies on transparent governance processes, mutual regulation, and participatory engagement to steer, legitimize, and transform service delivery. Emphasis is placed on coordinated efforts that empower enterprises, serve citizens, and foster continuous learning and innovation across sectors.

6. DISCUSSION AND CONCLUSION

This review has explored the contours and complexities of digital era governance (DEG), presenting it as a powerful quasi-paradigm that offers a renewed lens to understand public administration's evolution in the age of data, robotics, and artificial intelligence (AI). The discussions have moved beyond the foundational first and second waves of DEG and focused on the emergent third wave, characterized by deeper integration of digital systems, data science and AI (DSAI), and robotics. Central to this transition is the

model of Intelligent Centre and Devolved Delivery (ICDD), which embodies a dual structure of governance in the digital age. At the core, centralized "intelligent centres" powered by cloud-based data lakes, AI modelling, and optimization techniques are tasked with planning, simulating, and overseeing governance processes in real time. These centralized structures represent the shift from static, statistics-based performance metrics towards dynamic feedback dashboards that allow governments to continuously monitor and adjust policies. In contrast, "devolved delivery" structures represent the distributed face of the state—agencies closer to citizens delivering in-person services, deeply informed by local knowledge and supported by increasingly commodified and embedded robotic technologies. The juxtaposition of these two approaches, illustrated in Table 3 and conceptually mapped in Figure 3, reflects the dual imperatives of central optimization and local responsiveness that underpin DEG's architectural innovation.

Table 1 outlines how the three waves of DEG have unfolded across three key dimensions: digitalization (Column A), vertical integration (Column B), and horizontal holism (Column C). In earlier waves, digitalization focused on shifting analog systems to digital forms, while the second wave pushed for online service delivery and cost-efficiency through "digital by default" strategies. The third wave, as this article demonstrates, marks a more sophisticated turn, one where intelligent technology are integrated with physical-world interactions, enabling robotic systems to autonomously regulate, intervene, and support frontline public services. These robotic developments, detailed in Table 2, range from biometric gates at borders to service robots assisting in healthcare and automated infrastructure controls in flood management. They embody the emergence of the "robotic state"—a government increasingly capable of intervening in real-time, physical environments through machine-based systems. Figure 1 aptly conceptualizes this development by illustrating how governance processes now engage dynamically with citizens and enterprises, facilitating both regulatory and service-oriented feedback loops mediated through digital tools. This image captures how governments steer, empower, regulate, and serve through a continuous cycle of information transformation and citizen engagement.

Equally transformative is the discussion of administrative holism. While ICDD addresses the vertical dimension of governance—who does what within state structures—administrative holism addresses the horizontal dimension: how different agencies within the same tier collaborate, share expertise, and avoid redundant or siloed efforts. As digital marketplaces disrupt traditional industry-specific regulations—whether through Uber bypassing transport rules or AI influencing election regulation—there is a pressing need for coordinated, cross-agency DSAI expertise. This is not merely a policy imperative but an operational necessity, as shown by emerging collaborations like those between the UK's Financial Conduct Authority and the Competition and Markets Authority. In such settings, AI regulation, consumer protection, and digital transparency must be aligned, yet few governments have the institutional readiness or horizontal capacity to manage this effectively. Figure 2 captures the architectural logic of administrative holism, showcasing the evolving governance process where legitimacy, disclosure, empowerment, and transformation interweave between government, enterprises, and citizens. Administrative holism thus emerges not only as a technical configuration but as a normative ideal—an ambition to unify data flows and policy intentions across fractured institutional geographies.

The COVID-19 pandemic dramatically underscored the costs of failing to achieve this holism. Countries like the United States faced a twenty-first-century crisis with nineteenth-century bureaucratic architectures. Fragmented data systems, ideological disputes between government tiers, and disjointed public communication exemplified what happens when vertical and horizontal integration fails. On the contrary, nations that coordinated epidemiological and economic modelling, shared anonymized data effectively, and built collaborative digital infrastructures fared better both in crisis response and in public trust. These lessons reinforce the necessity of building administrative capacity that is both horizontally collaborative and vertically streamlined. Moreover, the pandemic exposed the limits of "legacy NPM" systems, where attempts to automate or simplify social welfare delivery—such as Australia's infamous "robodebt" algorithm or the UK's flawed school exam grading AI—resulted in public backlash, legal failure, and harm to vulnerable groups. These incidents remind us that public interest must remain central to all algorithmic and robotic deployments in governance.

A recurring insight throughout this review is that technological transformation alone is insufficient. Realizing the promises of DEG requires governments to address institutional inertia, develop cross-disciplinary digital literacy, and build ethically grounded AI infrastructures. This includes the imperative to pool scarce DSAI expertise at the national level—especially where smaller regulators or local governments cannot attract or retain such talent. Yet it also includes the need to cultivate local innovation using open-source technologies and participatory data platforms that engage communities directly. Cloud computing provision, as discussed under administrative holism, is helping to break up rigid IT outsourcing models and allows governments to reimagine service delivery with greater flexibility. When paired with simulations and agent-based models (as proposed by Axtell, 2018),

governments can run policy interventions virtually before implementing them, thus reducing risk and improving design quality. Such approaches are especially important in high-stakes domains like macroeconomic planning, health triage, and defense preparedness.

What emerges from the synthesis of evidence in this article is a new institutional logic—a fifth structural pressure alongside those explained in traditional political economy models. While welfare economics favored decentralized scale responsiveness, and macro-financial models emphasized national redistribution, DEG introduces a productivity-focused logic for functional allocation. Intelligent centres aggregate data, model national trends, and forecast systemic risks; devolved delivery systems adapt those insights to particular communities and operational realities. This institutional design is both analytically distinct and practically indispensable in the digital era.

In conclusion, DEG is more than a technological project—it is a re-foundation of how the state operates. Intelligent centres and devolved delivery agencies must operate symbiotically, supported by holistic administrative strategies and robust DSAI ecosystems. The challenges are many: algorithmic bias, regulatory fragmentation, talent shortages, and citizen trust deficits. But the opportunities are transformative. When implemented thoughtfully, DEG holds the potential to dramatically improve public sector productivity, responsiveness, and legitimacy. Future governance will not be determined solely by how many robots or algorithms are deployed, but by how effectively they are embedded into public value systems, ethical frameworks, and institutional practices that center the citizen. The third wave of DEG thus marks not the end of administrative reform, but its intelligent reinvention.

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