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Philosophical Foundations of Digital twin-based IT Governance: A Philosophy-of-Science Perspective

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ABSTRACT

The increasing adoption of digital twins in organisational settings has extended their use beyond technical optimisation toward decision support and governance functions. However, existing studies on digital twin-based IT governance largely emphasise technical architectures and performance considerations, while paying limited attention to the philosophical assumptions that shape how these systems represent reality, generate knowledge, and influence decision-making. This paper addresses this gap by examining digital twin-based IT governance through a philosophy-of-science perspective. Drawing on concepts from ontology, epistemology, and scientific modelling, this study conceptualises digital twins as socio-technical artefacts that function simultaneously as models and interventions. The analysis demonstrates that digital twins embed specific assumptions about what constitutes organisational reality, what forms of knowledge are considered valid, and how governance actions are legitimised. These assumptions have direct implications for accountability, transparency, and human agency in IT governance processes. Based on this analysis, the paper articulates design implications for digital twin-based IT governance, highlighting the importance of interpretability, human-in-the-loop mechanisms, reflexive design, and value-sensitive approaches. Rather than offering empirical generalisations, the contribution of this paper is conceptual: it provides a structured analytical framework that clarifies the foundational assumptions underpinning governance-oriented digital twins. The paper concludes by outlining directions for future empirical and design-oriented research aimed at developing digital twin-based governance systems that are not only technologically effective but also epistemically robust and socially responsible.

1. Introduction

Advanced computational technologies continuously reconfigure organisational processes and governance mechanisms within modern socio-technical domains. The preceding analysis demonstrates a critical tension: while digital twins are ontologically framed as objective mirrors and epistemologically driven by quantifiable data, governance inherently requires subjective interpretation, normative judgment, and contextual flexibility. Among these technologies, digital twins virtual representations of real-world systems that evolve over time are increasingly widely recognised as key tools for enabling real-time monitoring, simulation, and intervention across multiple sectors. A digital twin is understood as a bidirectionally coupled virtual representation of a physical or social system using continuous flows of data and computational models to mirror the state of the system over time [1].

The rapid uptake of digital twins is particularly evident in domains such as engineering, manufacturing, and smart cities, where they are employed to enhance performance, resilience, and decision making. For instance, digital twins have been proposed as key enablers of sustainable and responsive urban infrastructure by integrating sensor data with predictive

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analytics to support governance in complex environments [2]. However, despite this technological enthusiasm, the application of digital twins to IT governance and policy systems has remained nascent and often conceptually under-articulated. This oversight is particularly noticeable in the context of governance, where technologies are not only tools but also performative artefacts that shape how organisations define, measure, and enforce norms, compliance, and strategic objectives.

Conventional research on digital twin applications has predominantly focused on technical architectures, implementation challenges, and performance outcomes. For example, recent studies in the smart cities domain emphasise how digital twin platforms support monitoring, predictive capabilities, and operational efficiency through IoT, AI, and cloud-based analytics [3]. Such work, while valuable, tends to treat governance as an operational endpoint rather than a philosophically articulated process of knowledge, representation, and action. This oversight matters because the deployment of digital twins in governance contexts is not merely a technical optimisation problem; it involves assumptions about what aspects of organisational reality are represented, how knowledge is justified, and whose decisions are prioritised.

Recognising the philosophical complexity behind digital twin technologies is thus essential. Recent efforts in the philosophy of digital twinning highlight that digital twin concepts rest on holistic and emergentist philosophical commitments, challenging reductionist modelling approaches and underscoring the epistemic and ontological choices embedded in twin architectures [4]. These foundations have implications for designing systems capable of capturing not only mechanistic behaviours but also socio-technical interactions, interpretive ambiguities, and normatively contested governance objectives.

Yet, there is still limited theoretical work that systematically interrogates these philosophical assumptions within the specific context of IT governance a domain where decisions about risk, compliance, accountability, and strategic alignment hinge upon both data-driven inferences and normative judgments. Without explicit engagement with foundational questions about ontology (what governance phenomena are represented), epistemology (how governance knowledge is justified), and modelling assumptions (what counts as a valid representation), governance twins risk reinforcing technocratic biases or privileging formally measurable aspects at the expense of contextual meaning and human judgment.

To address this gap, this paper offers a philosophy-of-science perspective on digital twin-based IT governance. Rather than conducting a systematic review, we aim to elucidate the implicit philosophical commitments that shape how digital twins are understood and applied in governance contexts. Our contributions are threefold:

1. We articulate ontological and epistemological assumptions that underlie current conceptions of digital twin governance frameworks, highlighting tensions between representational models and socio-normative realities.
2. We critically examine how conceptual models of governance twins encode values and assumptions, including potential technocratic biases and implications for interpretive understanding.
3. We propose design principles and evaluative criteria grounded in philosophy of science that can guide reflexive development and use of governance twin systems, ensuring alignment with broader organisational and societal objectives

Therefore, this study addresses the following overarching research question: How do ontological and epistemological assumptions shape the design, interpretation, and legitimacy of digital twin-based IT governance systems? By foregrounding the philosophy of science in the study of digital twin governance to answer this question, this paper seeks to bridge conceptual and practical perspectives, offering a foundational lens for future theory development, design science inquiry, and critical socio-technical research.

2. Research Approach and Methodology

This paper conducts a conceptual and theoretical study rather than an empirical investigation. The research approach employs a philosophy-of-science analytical framework to critically examine the foundational premises of digital twin technologies within IT governance. By systematically unpacking the ontological (what exists) and epistemological (how knowledge is justified) dimensions, this methodology allows for the evaluation of implicit assumptions that technical architectures often obscure.

To analyse digital twin-based IT governance beyond technical implementation concerns, this paper adopts a philosophy-of-science perspective as its primary analytical lens. Philosophy of science provides conceptual tools for examining how knowledge claims are constructed, justified, and operationalised within scientific and technological practices. In the context of socio-technical systems, such as IT governance, this perspective is particularly valuable because governance mechanisms embody not only technical representations but also normative assumptions about authority, responsibility, and rational decision-making.

A widely accepted framework within philosophy of science distinguishes between three interrelated dimensions: ontology, epistemology, and methodology. Ontology concerns assumptions about what kinds of entities are taken to exist and be relevant; epistemology addresses how knowledge about these entities is produced and validated; and methodology refers to the practices, models, and evaluation criteria through which inquiry is conducted. These dimensions have long been recognised as foundational for understanding scientific modelling and theory construction, including in applied and interdisciplinary fields such as information systems [4].

In information systems research, philosophical reflection has been repeatedly emphasised as essential rather than optional. Hirschheim and Klein argue that all information systems research implicitly enacts philosophical positions, whether acknowledged or not, and that failure to articulate these positions can lead to conceptual ambiguity and methodological inconsistency. From this perspective, technologies such as digital twins are never neutral artefacts:

they encode particular views of organisational reality, prioritise certain forms of knowledge, and marginalise others [4].

Recent studies in philosophy of science further highlight the role of models as epistemic mediators rather than mere mirrors of reality. Scientific models are understood as idealised and purpose-driven constructions that enable reasoning, prediction, and intervention, while inevitably simplifying or omitting aspects of the phenomena they represent. This insight is especially relevant for digital twin systems, which combine computational models, real-time data, and decision-support functions. Without philosophical scrutiny, such systems risk being interpreted as objective representations of reality, obscuring the interpretive and normative choices embedded in their design.

Within the broader digital transformation literature, scholars have warned that neglecting epistemological and ontological reflection may reinforce technocratic and reductionist tendencies, particularly when digital systems are used to govern human behaviour and organisational processes. Studies in digital governance and management philosophy note that data-driven systems often privilege what can be formally measured and automated, while under-representing contextual understanding, human judgment, and ethical considerations [5]. Similar concerns are echoed in management and organisational studies, where philosophical analysis is seen as necessary to ground digital innovation in coherent conceptual and normative frameworks [6].

Against this background, this paper employs a philosophy-of-science lens to make explicit the ontological and epistemological assumptions embedded in digital twin-based IT governance. Rather than treating digital twins as purely technical solutions, we examine how they construct governance realities, legitimise particular knowledge claims, and shape evaluative criteria for compliance, risk, and performance. This analytical perspective provides the conceptual foundation for the subsequent sections, which interrogate how digital twins function simultaneously as representations of governance and as interventions that actively shape organisational practice.

Figure 1 The figure presents a comprehensive conceptual framework for analysing digital twin-based IT governance through a philosophy-of-science perspective. At the top level, digital twin-based IT governance is grounded in a set of philosophical assumptions consisting of ontology, epistemology, and modelling. Ontology addresses what aspects of organisational and technological reality are assumed to exist and can be represented within a digital twin. Epistemology concerns how knowledge about governance processes is constructed, validated, and justified. Modelling highlights the role of digital twins not only as representations but also as interventions that shape actions and influence organisational behaviour.

These three philosophical dimensions intersect within the core of the framework, forming the philosophical foundation of digital twin-based IT governance. Their intersection illustrates that governance outcomes emerge from the combined assumptions about reality, knowledge, and modelling practices rather than from any single dimension in isolation. Building on this philosophical foundation, the framework identifies key design and evaluation implications, including human-in-the-loop mechanisms, validation strategies, and ethics and accountability. Together, these elements demonstrate how abstract philosophical commitments are translated into concrete design principles and evaluation criteria for responsible and effective digital twin-based IT governance.

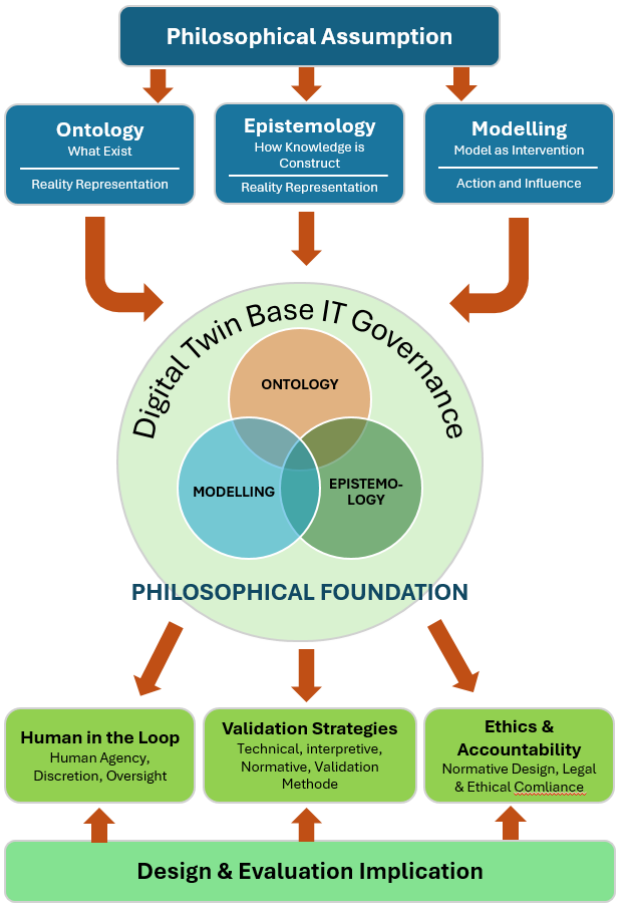

Figure 1 Digital twin-based IT governance flowchart

3. Results and Discussion

3.1 Ontological and Epistemological Assumptions in Digital twin-based IT Governance

In order to critically analyse the foundations of digital twin-based IT governance, it is necessary to make explicit the ontological and epistemological assumptions that underlie how digital twins are conceived, represented, and used within organisational decision-making systems. Ontological assumptions pertain to the categories of entities and structures that are presumed to exist in a governance twin, including what aspects of organisational reality are deemed meaningful, measurable, or relevant. Epistemological assumptions concern how knowledge about these entities is generated, validated, and justified, as well as the criteria used to assess the truth, reliability, and legitimacy of that knowledge [9]. Philosophical inquiry into these dimensions reveals implicit commitments that shape both the design and the use of governance twins, with significant implications for organisational practice and policy.

3.1.1 Ontological Assumptions: What Is Being Represented?

The ontological commitments embedded in digital twins reflect what kinds of things are taken to exist and matter in a given domain. In technical and engineering contexts, digital twins are often framed as models or replicas of physical systems, with a focus on capturing observable variables and functional relationships between components. However, this representational ontology assumes that organisational phenomena such as compliance, risk, and strategic alignment can be sufficiently captured through data, metrics, and computational models—an assumption that may overlook the complexity and emergent nature of socio-technical governance processes [7]. In their influential philosophical analysis of digital twins, Korenhof et al. argue that digital twins are not merely digital representations but rather steering tools that actively shape physical and social systems by privileging certain viewpoints and objectives most notably efficiency and optimisation over others. This relabels the ontological status of digital twins: from mirrors of reality to instruments that instantiate and reinforce particular goals and priorities [7].

From an information systems perspective, the ontological commitments of digital twins also arise in decisions about knowledge representation, abstraction, and categorisation. Ontologies and semantic models, for example, are used in many digital twin frameworks to provide a structured vocabulary and schema for data integration and reasoning. In industrial and cyber-physical systems, ontological models help specify relationships between entities, behaviours, and processes, thereby grounding digital twins in a formal conceptualisation of domain knowledge [8]. However, this ontological ordering depends on choices about what to include or exclude, how to classify phenomena, and what level of granularity is relevant choices that are often made implicitly and reflect epistemic priorities within particular disciplines or stakeholder groups.

In IT governance, these assumptions become especially consequential because governance phenomena involve not only technical behaviours but also human interpretations, institutional norms, and contingent practices. A purely data-centric ontology risks framing governance reality in terms of what can be quantified and automated, marginalising aspects such as discretionary judgment, interpretive understanding, and organisational values. Thus, ontological reflection requires recognising that digital twin governance systems are not neutral windows into reality but conceptual artefacts shaped by particular metaphysical and pragmatic commitments about what exists and matters.

3.1.2 Epistemological Assumptions: How Knowledge Is Constructed and Validated

Alongside ontology, epistemological assumptions relate to how digital twin systems produce, justify, and legitimate knowledge. Most digital twin frameworks adopt a data-driven epistemology in which real-time sensor data, historical records, and computational simulations are treated as the primary sources of valid knowledge about the system of interest. This reflects a form of empiricist reasoning in which knowledge claims about system states, trends, or predictions are grounded in quantifiable measurements and algorithmic outputs. While this approach is powerful for operational monitoring and predictive capabilities, it carries implicit assumptions about the nature of understanding and explanation. In particular, it suggests that accurate predictions and high-fidelity simulations constitute sufficient justification for knowledge claims. Yet in governance contexts, justification of knowledge often requires interpretation, context-sensitivity, and normative judgement—dimensions that cannot be reduced to statistical or computational adequacy alone. For example, understanding the meaning of compliance or ethical behaviour in a given organisational culture often depends on interpretive insights not directly reducible to sensor signals or model outputs.

Moreover, digital twins typically assume an epistemic symmetry between models and reality, whereby a sufficiently rich model is presumed to approximate real system behaviour closely enough to inform decision making. This assumption echoes broader debates in philosophy of science about the status of models as representations versus instruments of intervention. Korenhof et al. critique this assumption by pointing out that digital twins do not simply reflect reality but can steer the systems they represent toward predefined goals, often privileging optimisation while masking interpretive and normative dimensions of governance problems [9].

Another epistemological consideration concerns the criteria used to evaluate knowledge produced by digital twins. Traditional validation criteria in engineering and computer science emphasise accuracy and predictive performance. However, from a philosophical standpoint, additional criteria such as explanatory power, interpretability, and normative legitimacy are equally important in governance contexts. Digital twin systems that prioritise only technical validation risk epistemic narrowing, in which the scope of what counts as valid knowledge is constrained by technological capabilities rather than by organisational and social considerations.

3.1.3 Tensions and Consequences for IT Governance

The ontological and epistemological assumptions highlighted above interact in ways that have significant implications for IT governance. First, by prioritising quantifiable entities and algorithmic processes, digital twin systems can lead to reductionist framings of governance reality that overlook socio-institutional dynamics, human interpretations, and contested meanings. Second, the epistemic focus on data and simulation reinforces a technocratic rationality that privileges optimisation and risk minimisation over deliberation and ethical judgement. These tendencies can create governance blind spots, where important dimensions of organisational life are rendered invisible or irrelevant to the twin's evaluative logic.

Recognising these tensions suggests that digital twin-based governance systems should be designed with explicit philosophical reflection about what is represented, how knowledge is justified, and how decisions are legitimised. This includes considering hybrid approaches that integrate data-driven insights with interpretive and normative frameworks, as well as questioning the assumptions that underpin modelling choices and representational commitments. In doing so, governance twins can move beyond narrow technical optimisation and support more holistic, reflexive, and context-sensitive forms of governance.

3.2 Digital Twins as Models and Interventions

Digital twins are often introduced in both academic and practice settings as models specifically, dynamic representations that reflect the state and behaviour of physical systems over time. However, beyond simply being advanced simulations or replicas, digital twins function as interventions that influence the systems they represent. This dual role has significant implications for how digital twins are conceptualised in IT governance contexts, encompassing issues of representation, agency, and action.

3.2.1 Digital Twins as Evolved Models

From a modelling perspective, digital twins represent a next evolutionary stage in modelling paradigms, distinguished by real-time connectivity between physical systems and their virtual counterparts. Traditional models in engineering and management are static or episodic snapshots of systems, often used for design-time analysis or hypothetical scenario evaluation. In contrast, digital twins maintain continuous, bi-directional flows of information that support live decision-making processes and feedback loops [10]. In essence, a digital twin is not merely a passive model but a continuously updated abstraction that evolves with the system it represents, incorporating real-time data, analytics, simulation, and prediction. For example, characterises digital twins as a logical progression of modelling practices in systems engineering. Here, digital twins integrate traditional model artefacts with data-driven updates and analytical capabilities, forming a hybrid construct that blurs the boundary between model and system. This evolution highlights that digital twins are not only conceptual representations but also operational artefacts embedded within socio-technical infrastructures[11].

In operational settings such as supply chains, digital twin models are elaborated into complex decision-support frameworks that combine data streams, organisational models, and decision logic. Recent work in this area emphasises the integration of data-driven and object-driven modelling approaches to support dynamic decision-making, resilience analysis, and adaptive control within cyber-physical ecosystems [12]. Such frameworks demonstrate how digital twins serve as models of system behaviour and structure, while simultaneously enabling prescriptive and predictive functions that influence real operations.

3.2.2 Models as Interventions: From Representation to Action

Beyond their representational function, digital twins act as interventions mechanisms that do not just reflect reality but also shape how systems behave and how decisions are made. In socio-technical governance contexts, this performative dimension means that digital twins can alter decision landscapes, redistribute agency among human and machine actors, and reframe what counts as actionable knowledge.

In urban and infrastructure domains, for example, digital twin representations have been deployed to model interdependencies across critical systems (e.g., water, transportation, power), not simply to observe these networks, but to simulate crisis scenarios and prescribe adaptive responses that feed back into governance processes [12]. In such cases, the twin becomes a tool of intervention informing emergency planning, resource allocation, and risk mitigation.

This interventionist role amplifies the inherent power of digital twins as decision support artefacts. They do not merely display system states; they influence how stakeholders prioritise problems, attribute responsibility, and allocate resources. In governance for example, a twin that continuously updates compliance indicators may lead organisations to prioritise measurable metrics even when more nuanced interpretive assessments are required a phenomenon that mirrors concerns raised in the modelling literature about epistemic narrowing, where models shape not just understanding but also choices about action and accountability.

3.2.3 Implications for Governance

The reconceptualisation of digital twins as both models and interventions invites a deeper examination of their role in governance systems. First, it foregrounds the idea that models embedded in digital twins carry assumptions about what phenomena are relevant, how relationships are structured, and what interventions are plausible or desirable. These assumptions are not neutral: they embed values about efficiency, optimisation, risk mitigation, and rationality into governance processes.

Second, framing digital twins as interventions highlights that their purpose extends beyond prediction to shaping organisational behaviour. Digital twins can implicitly encode governance priorities such as compliance thresholds, optimisation targets, or risk limits that guide organisational behaviours in ways that might not be transparent to stakeholders.

Finally, this perspective emphasises the importance of reflexive governance a mode of governance that explicitly recognises and interrogates the models and assumptions that underpin decision-support systems. This reflexivity is crucial if governance twins are to support not only technically efficient outcomes, but also socially legitimised and ethically acceptable decisions.

3.3 Implications for Designing Digital twin-based IT Governance

The ontological and epistemological analysis presented earlier has important consequences for the design of digital twin-based IT governance systems. If digital twins are not neutral models but embedded socio-technical artefacts that shape knowledge and practice, their design must move beyond technical optimisation to include philosophically grounded design principles and governance considerations. This section outlines several implications for how such systems should be conceptualised, structured, and evaluated to align with the complexities of organisational governance.

Our analysis reveals a critical tension. Ontologically, digital twins are framed as objective mirrors. Epistemologically, they rely heavily on quantifiable data. However, governance practice is inherently different; it requires subjective interpretation, normative judgment, and contextual flexibility. If this tension remains unaddressed, digital twin frameworks risk enforcing a rigid, technocratic control that undermines human agency. Therefore, the architectural and operational design of these systems must be

fundamentally reoriented. The design implications outlined below are not merely optional features; they are necessary theoretical requirements to bridge the gap between algorithmic outputs and legitimate governance actions.

3.3.1. Designing for Interpretability, Accountability, and Trustworthiness

An immediate implication of the philosophical scrutiny of digital twins is that interpretability and accountability must be core design criteria. Digital twins that prioritise raw predictive performance without transparent traceability of decisions can undermine trust among stakeholders. For example, Larsen, Fitzgerald, and Woodcock argue that ensuring trustworthy digital twins requires frameworks, methods, and tools that systematically provide confidence that a twin is fit for purpose, including analyses of fidelity, feedback dynamics, and interaction protocols with human operators. Such design considerations are not merely technical but epistemic—they shape how users understand and justify decisions arising from twin-informed governance [14].

This aligns with broader calls in design science research for design principles that embody normative commitments, such as transparency and human understandability, rather than leaving them as by-products of system performance. Research on shared digital twins highlights how design principles can guide system architects in structuring data sharing, security, and interoperability in distributed contexts, emphasising that such principles are foundational for prescriptive guidance beyond domain-specific instances [13].

3.3.2. Governance-Oriented Design Principles

Digital twin-based IT governance should consciously integrate governance-oriented design principles criteria that ensure the twin supports legitimate, ethical, and reflective decision making rather than merely streamlining technical processes. Such principles could include:

a. Multi-Layered Validation
   Technical validation (accuracy, performance) needs supplementation with interpretive validation (meaningful explanations to humans) and normative validation (alignment with organisational values and compliance requirements). Without multi-layered validation, governance systems risk privileging what is measurable over what is socially relevant.
b. Human-in-the-Loop Design
   Governance decisions often depend on human interpretation, discretion, and ethical judgement. Digital twins should be designed to involve humans in interpretation, override, and contextualisation, rather than automating decisions to the point of eroding human agency. This is consistent with literature advocating for participatory or co-design approaches in complex socio-technical systems.
c. Reflexive Interfaces and Feedback
   Design should support reflexivity, enabling stakeholders to query how decisions arise, what assumptions were used, and how alternative scenarios might unfold. This not only increases transparency but also strengthens accountability frameworks anchored in governance theory [15].

3.3.3. Modular and Scalable Design Frameworks

From a practical systems engineering perspective, digital twins must be modular and scalable to support evolving governance needs. Human, Basson, and Kruger propose a systematic framework for designing digital twins and services using modular strategies such as decomposition of physical systems, services allocation, and verification ensuring that twins can integrate various governance functions (e.g., compliance monitoring, risk assessment, strategic planning) without rigid monolithic architectures. By adopting modular design, governance twins can flexibly adapt to new policy requirements or organisational changes without necessitating wholesale redesign [15].

This implication shows that design decisions have far-reaching effects not only on functional capabilities but also on the practical governance agility of organisations, especially in dynamic technology environments.

3.3.4. Embedding Legal and Ethical Compliance by Design

Beyond technical and organisational concerns, legal and ethical compliance needs to be embedded in the design of digital twins. Digital twin systems increasingly intersect with complex regulatory landscapes, such as the European Union frameworks on privacy, data governance, and cybersecurity, which collectively require that digital systems be created with compliance-by-design methodologies that prioritize transparency, accountability, and data protection. This means governance twins should not only embed technical compliance mechanisms but also be structured to ensure explainable decision logic and clear accountability pathways that reflect regulatory expectations [16].

By adopting a compliance-by-design mindset, digital twin-based governance systems can mitigate regulatory risks while reinforcing trust and legitimacy among stakeholders, both internal (e.g., employees, managers) and external (e.g., regulators, citizens, partners).

3.3.5. Towards Value-Sensitive and Inclusive Design

Finally, design implications point towards value-sensitive design approaches that explicitly accommodate diverse stakeholder values and ethical concerns. Value-sensitive design considers human values throughout the technological development process and has been widely discussed in information systems as a normative framework for ethical technology construction. Such approaches ensure that twins reflect not only technical objectives but also the social, ethical, and organisational values of the governance contexts in which they function [17].

For digital twin-based IT governance, this means actively engaging users in articulating value priorities (e.g., fairness, equity, inclusivity) and embedding these into design requirements, validation criteria, and policy configurations.

3.4 Limitations and Future Research

This paper adopts a conceptual and philosophy-of-science perspective to analyse the foundations of digital-twin-based IT governance. While this approach enables deep reflection on ontological and epistemological

assumptions, it also entails several limitations that should be acknowledged and that open avenues for future research.

3.4.1. Limitations of the Study

First, this study is conceptual rather than empirical. The arguments developed in this paper are grounded in philosophical analysis and a selective engagement with representative literature, rather than in systematic empirical validation or large-scale case studies. As a result, the claims advanced here should be understood as analytical and normative propositions rather than empirically generalisable findings. This limitation is inherent to conceptual research, which aims to clarify assumptions and frameworks rather than to test hypotheses [19].

Second, the paper relies on a non-exhaustive body of literature drawn from information systems, digital twin research, and philosophy of science. Although the cited works represent influential and well-established contributions, the analysis does not claim comprehensive coverage of all existing perspectives. Different disciplinary traditions such as critical data studies, organisational sociology, or legal theory may emphasise alternative assumptions and raise additional concerns that are not fully explored here. Similar limitations have been acknowledged in conceptual studies that prioritise depth of analysis over breadth of coverage [18].

Third, the philosophical lens adopted in this paper is primarily situated between critical realism and design science traditions. While this positioning allows for productive engagement with socio-technical modelling and governance artefacts, it may under-represent more radical interpretive or post-structural perspectives that question the very possibility of stable representations of governance. Consequently, the analysis may not fully capture power relations, discursive struggles, or political dynamics that shape IT governance in practice. This reflects a broader challenge in information systems research, where philosophical positioning necessarily foregrounds some dimensions while backgrounding others.

Finally, the discussion remains at the level of conceptual implications for design, rather than providing detailed technical architectures or implementation guidelines. While this is consistent with the paper's philosophical aims, it limits the immediate applicability of the findings for practitioners seeking concrete system specifications. The translation of philosophical design principles into operational artefacts therefore remains an open challenge.

3.4.2 Directions for Future Research

Building on these limitations, several promising directions for future research can be identified. First, empirical studies are needed to investigate how digital-twin-based governance systems are actually designed, implemented, and used in organisational settings. Qualitative case studies, ethnographic research, or action research could examine how ontological and epistemological assumptions materialise in practice, how stakeholders interpret twin-generated insights, and how these systems influence decision-making and accountability.

Second, future work could integrate design science research with explicit philosophical reflection. Rather than treating philosophy as a post-hoc critique, researchers could embed ontological and epistemological analysis directly into the design cycles of governance twins. This would enable systematic experimentation with alternative modelling assumptions, validation criteria, and human-in-the-loop mechanisms, thereby advancing both theory and practice [20].

Third, there is a need for interdisciplinary research that bridges information systems, law, ethics, and public administration. Digital-twin-based IT governance increasingly intersects with regulatory frameworks, ethical principles, and societal expectations. Future studies could explore how governance twins align with legal requirements, support transparency and explainability, and accommodate normative pluralism in complex institutional contexts.

Finally, future research could develop evaluation frameworks that move beyond technical accuracy to assess governance twins in terms of legitimacy, fairness, and organisational learning. Such frameworks would operationalise the philosophical insights advanced in this paper and provide practical tools for assessing whether digital-twin-based governance systems contribute to responsible and reflective forms of digital governance.

In sum, while this paper provides a conceptual foundation for understanding digital-twin-based IT governance through a philosophy-of-science lens, it also highlights the need for sustained empirical, design-oriented, and interdisciplinary research to translate philosophical insight into robust governance practice.

4. Conclusion

This paper has examined the foundations of digital twin-based IT governance through a philosophy-of-science perspective, arguing that digital twins should not be understood merely as advanced technical tools or simulations, but as socio-technical governance artefacts embedded with ontological and epistemological assumptions. By foregrounding these assumptions, the paper contributes to a deeper conceptual understanding of how digital twins shape organisational knowledge, decision-making, and accountability in governance contexts.

The analysis shows that digital twins simultaneously function as models and interventions. As models, they represent organisational and technological realities through selective abstractions that define what is observable, measurable, and actionable. As interventions, they actively influence governance processes by shaping decision frames, redistributing agency between human and computational actors, and embedding normative priorities such as efficiency, compliance, and optimisation. Recognising this dual role is crucial for avoiding naïve or technocratic deployments of digital twin-based governance systems.

From a design perspective, the paper highlights that effective digital twin-based IT governance requires more than technical accuracy. It demands interpretability, reflexivity, and value sensitivity by design, as well as explicit mechanisms for human oversight and accountability. Embedding these principles helps ensure that governance twins support legitimate and responsible decision-making rather than reinforcing opaque or overly automated forms of control.

Overall, this study positions philosophy of science as a productive analytical lens for understanding and designing digital twin-based IT governance. By clarifying these foundational assumptions, this conceptual framework provides a direct roadmap for both practice and academia. For future empirical research, this framework guides scholars to investigate how organisations navigate the tensions between data-driven models and human discretion in real-world policy settings. For practitioners and system architects, it informs the responsible design of IT governance systems by mandating features such as algorithmic interpretability, ethical compliance mechanisms, and human-in-the-loop protocols. Ultimately, integrating these philosophical dimensions ensures that the next generation of digital twin governance systems will be not only technologically sophisticated but also epistemically robust and socially responsible.

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