IT TAKES TWO TO CO-CREATE - DIGITAL TWIN MECHANISM FOR VALUE CO-CREATION

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The convergence of physical assets and dynamic digital representations is reshaping how value is created in service ecosystems. Digital twins (DTs) are at the center of this development, yet a comprehensive understanding of how they influence the co-creation of value remains lacking. A systematic literature review of 53 peer-reviewed articles on DTs in service ecosystems was conducted. Drawing on service-dominant logic (SDL) as an analytical lens and expanding this perspective with Giddens' theory of structuration, the analysis identifies five mechanisms: real-time mirroring and synchronization, simulative anticipation and scenario experimentation, feedback-driven adaptive learning and reconfiguration, interactive co-creation and participatory design, and cross-boundary resource orchestration. Building on these two theoretical perspectives, a conceptual framework is developed that positions DTs as socio-material mediators of structuration in service ecosystems. In doing so, the SDL discourse is expanded by illustrating how digital technologies condition and transform resource integration, while offering implications for DT-based service design.

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1 Introduction

Technological advances in industry, energy, infrastructure and mobility are enabling increasingly dynamic and intelligent service offerings (Alter, 2020). These services emerge within service ecosystems, where stakeholders are connected through the exchange of services (Lusch & Nambisan, 2015). Digital twins (DTs) are establishing themselves as a key technology in these sectors, linking physical assets to digital representations via continuous data streams and enabling smart services through simulation and operational control (Enrique & Soares, 2022; Grieves & Vickers, 2017; Lim et al., 2020; Wache, 2023). Although Service-Dominant Logic (SDL) is often used to conceptualise value creation in such contexts (Schmidt et al., 2026), it only partially explains how DTs influence value creation processes.

Recent research, particularly in the context of digital platforms, has begun to examine how specific digital technologies shape interactions, coordination, and innovation (Schmidt et al., 2026). For instance, some scholars argue that DTs should be understood as resources used by interdependent actors to integrate information and co-create value within networks (Camposano et al., 2021). Other emerging frameworks draw on SDL to explain how DTs structure value-creation processes, such as adaptability and responsiveness, through resource integration in service design (Zarco, 2024). However, existing research remains fragmented and predominantly focuses on domain-specific approaches or isolated facets. However, a comprehensive conceptual explanation of how DTs enable value co-creation within service ecosystems remains lacking. In particular, it is unclear how DTs impose new conditions on value cp-creation and which facets are affected. This gap leads to the following research question (RQ): *How do digital twins shape value co-creation in service ecosystems?*

This paper addresses this gap by conceptualizing DTs as a factor that affects resource integration and value co-creation. Two interrelated objectives are pursued. First, the central mechanism through which DTs influence resource integration for value co-creation are identified. Second, a conceptual framework illustrating the ideal-typical integration of DTs is developed. This represents a first step toward extending SDL to account for artifact-mediated resource integration in value co-creation, with DTs as a paradigmatic case.

The remainder of this paper outlines the theoretical foundation, methodology and identifies five mechanisms through which DTs shape value co-creation. Finally, a conceptual framework is proposed, positioning DTs as socio-material mediators and conclude with implications, limitations, and future research.

2 Foundation

2.1 Service-Dominant Logic

According to the SDL conceptualization, value is not inherent in goods but emerges as the result of resource integration through the exchange of services between actors in service ecosystems (Lusch & Nambisan, 2015; Vargo & Lusch, 2016). Value co-creation is the collaborative process in which actors apply their knowledge and skills (operant resources) to integrate physical goods, data, and other resources (operand resources) in context, thereby realizing utility value (Lusch & Nambisan, 2015; Vargo & Lusch, 2016). Service ecosystems are accordingly self-regulating systems of resource-integrating actors coordinated by institutional arrangements. Vargo & Lusch (2016) distilled five axioms from this perspective, summarized in Table 1.

Table 1: The axioms of S-D logic according to Vargo & Lusch (2016)

Axiom	Description
1	Service is the fundamental basis of exchange.
2	Value is co-created by multiple actors, always including the beneficiary.
3	All social and economic actors are resource integrators.
4	Value is always uniquely and phenomenologically determined by the beneficiary.
5	Value cocreation is coordinated through actor-generated institutions and institutional arrangements.

Source: Vargo & Lusch (2016)

2.2 Technology and Resource Integration

Although SDL has traditionally emphasized human and organizational actors, the role of technology in value co-creation is increasingly recognized (Barile et al., 2021). Digital technologies shape processes of co-design, co-development, co-delivery, and co-learning across all levels of service ecosystems (Barile et al., 2020), yet existing analyses often treat technologies as enablers or platforms without explaining how specific artifacts influence the conditions under which resources become visible, combinable, and coordinable (Barile et al., 2020). In data-intensive environments, digital artifacts possess material properties enabling actors to manage visibility and control resources across organizational boundaries (Balta et al., 2021; Herterich et al., 2016; Payne et al., 2021a). This allows digital technologies to become structure-forming element for resource combination (Adi et al., 2023). As AI-based systems increasingly sense, learn, and adapt autonomously, artifacts develop their own agency and participate in decision-making, therefore transforming service system configurations (Barile et al., 2021; Hwang et al., 2026; Mele & Russo-Spena, 2024; Payne et al., 2021b).

SDL alone does not fully explain how digital artifacts shape value creation. Structuration theory (Giddens, 1984) addresses this by conceptualizing structure as recursively produced through action. This aligns with SDL, where rules and norms both enable and are shaped by value creation (Vargo & Lusch, 2016). Here, structure corresponds to institutional arrangements (Axiom 5), while resource-integrating practices reflect agency (Axioms 1 and 3). While Giddens largely neglects technology, later work such as sociomateriality (Orlikowski, 2007) emphasizes the entanglement of technological artifacts and social practices, a link also reflected in SDL.

2.3 Digital Twins as Mediating Artifacts

DTs link physical entities with virtual counterparts, enabling data-driven services such as monitoring and control (Grieves, 2014; Tao et al., 2018). While definitions vary (Tuegel et al., 2011; van der Valk et al., 2020), what distinguishes DTs from other digital artifacts is the simultaneous combination of a persistent virtual representation, bidirectional synchronization, and embedded simulation. From an SDL perspective, DTs function as platforms for service innovation, enabling actors to integrate information, dynamically adapt to customer needs, and jointly provide new services (Camposano et al., 2021; Stoll et al., 2020; Zarco et al., 2024).

Combining these perspectives yields an integrated analytical framework. SDL establishes that value emerges through collaborative resource integration coordinated by institutional arrangements. Structuration theory, extended by the sociomaterial lens, accounts for the recursive relationship between digital artifacts and the structures they enact and transform; the technology literature specifies how

DTs mediate this integration by making resources visible, enabling virtual experimentation, and coordinating actors (Zarco et al., 2024; Zhu et al., 2026). Together, these perspectives capture both the collaborative nature of value co-creation and the structural role of DTs in reconfiguring resource integration in service ecosystems.

3 Research Approach

A systematic literature review guided by Webster & Watson (2002) was conducted to identify and classify prior SDL studies examining how DTs shape value co-creation in service ecosystems. Following Paré et al. (2015), this study adopts a mapping approach to identify concept characteristics and derive underlying mechanisms.

The search was conducted across five relevant databases (see Figure 1). To ensure conceptual fit, articles were included if they (1) address DTs in service ecosystems, (2) align with the chosen conceptual definition of DTs, and (3) provide sufficient detail on resource integration, value co-creation, and institutional arrangements. The query combined "digital twin" and "service ecosystem" with related terms and was limited to English-language, peer-reviewed literature, resulting in 174 initial articles. After excluding duplicates, the remaining articles were screened for relevance, first based on titles and abstracts, and finally on the full text (Webster & Watson, 2002).

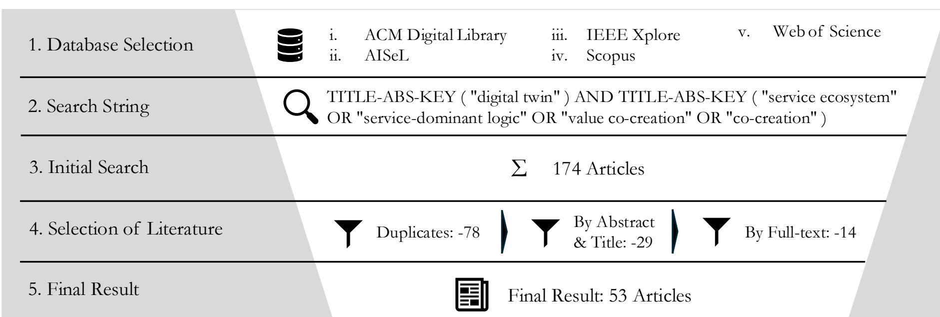

Figure 1: Overview literature research

Source: Own

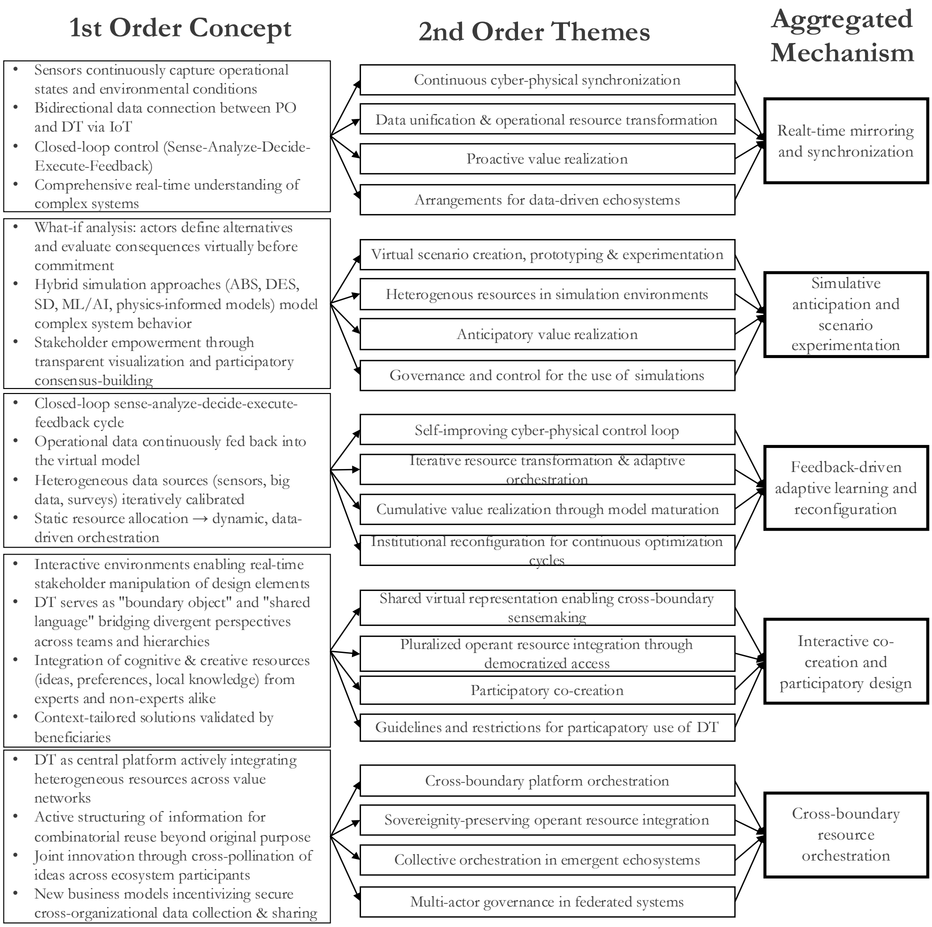

Figure 2: Data structure following the approach of Gioia et al. (2013)

Source: Own

This study adopts a multi-level coding approach inspired by Gioia et al. (2013), using SDL axioms as sensitizing devices to examine how resource integration, value creation, and institutional arrangements manifest in DTs. In the aggregation phase, structuration theory and its sociomaterial extension (Section 2) guided the organization of emerging themes along the duality of structure and actor practises. This two-layered strategy allowed us to ground first-order concepts in SDL vocabulary while situating the aggregated mechanisms within the broader dynamics of how digital artifacts condition and transform structural arrangements of service ecosystems.

Each article was systematically coded and reviewed, yielding first-order concepts that describe DTs within service ecosystems (Gioia et al., 2013). In a subsequent step, these codes were compared and iteratively refined. By continuously relating them to existing literature, particularly SDL concepts such as resource integration (Vargo & Lusch, 2016), common second-order themes were interpretively derived. Guided by the duality of structure and actor practices as an interpretive frame, captured themes were then aggregated into overarching mechanisms. Each mechanism is traceable to a distinct cluster of second-order themes (see Figure 2), that illuminate the role of DTs within service ecosystems and their interdependencies. Figure 2 shows the resulting data structure and presents a selective subset of first-order concepts.

4 Digital Twin SDL Supporting Mechanism

4.1 Real-time mirroring and synchronization

Real-time data acquisition and processing form the cornerstone of DT functionality, enabling the continuous mirroring and synchronization of physical systems within service ecosystems (Tao et al., 2018). Heterogeneous data is continuously integrated and synchronized with the twin, while advanced implementations offer bidirectional synchronization (van der Valk et al., 2020). This shifts resource integration from sequential, isolated data exchange to continuous, cross-domain access. Available data becomes a shared operational resource that multiple actors and systems can utilize simultaneously. Furthermore, situational awareness and accelerated decision-making are enhanced (Madeira et al., 2022). The mechanism also provides the foundational infrastructure for resource integration (Axiom 3) by transforming distributed data into a shared, dynamically accessible resource across the ecosystem.

4.2 Simulative anticipation and scenario experimentation

DTs function as anticipatory experimentation environments that enable actors to construct, manipulate, and evaluate alternative future states before intervening in the physical world (Verdugo-Cedeño et al., 2024). They integrate real-time and historical data, analytical models, and domain knowledge into prospective representations in which varying parameters and consequences can be explored (Meierhofer et al., 2020). Decision-making thus shifts from ex post reaction to ex ante evaluation. Actors can experiment with configurations in a low-risk setting, anticipate trade-offs prior to committing resources, and embed simulation-based evidence into organizational practices, fostering more proactive forms of coordination and governance (Bertoni, 2023). In SDL terms, this mechanism extends resource integration (Axiom 3) into the temporal domain, making potential future resource configurations evaluable. By embedding simulation-based evidence into decision practices, it simultaneously reshapes the institutional arrangements (Axiom 5) through which value co-creation is coordinated.

4.3 Feedback-driven adaptive learning and reconfiguration

As adaptive learning systems, DTs establish recursive feedback structures that continuously integrate operational data, user interactions, and service outcomes into digital models, transforming static representations into dynamically evolving systems (Zarco, 2024). This manifests as operational closed-loop adaptation, where sensory data informs model updates, and as stakeholder-driven reconfiguration, where user feedback shapes service adaptation (Cao & Ming., 2025). In both forms, DTs connect observation, simulation, and intervention within recursive learning loops, actively contributing to shaping the systems they represent. Value creation thus shifts from discrete optimization toward continuous adaptation, giving rise to new institutional requirements such as adaptive governance structures and frameworks for algorithmic decision-making in real-time contexts (Schultheiß et al., 2023). This mechanism enhances the recursive nature of resource integration (Axiom 3) by enabling continuous feedback, experimentation, and adaption. As a result, Axiom 4 becomes more operationally generative, since beneficiaries experimental value assessments can more directly inform subsequent service configurations and institutional arrangements (Axiom 5).

4.4 Interactive co-creation and participatory design

DTs function as co-creative environments in which multiple stakeholders collaboratively explore and refine solution concepts within a shared digital representation (Trizio et al., 2024). Rather than relying on sequential feedback, actors directly intervene in the design artifact by modifying parameters, testing alternatives, and observing effects in real-time. In doing so, DTs externalize diverse forms of knowledge and render them actionable through joint activity, shifting participation from passive involvement to active co-design of both problem definitions and solution spaces (Stoll et al., 2020). Through iterative cycles of interaction, evaluation, and adaptation, actors align their perspectives and converge on contextually grounded solutions, co-creating value not only in the outcome but throughout the process itself (Meske et al., 2021). So, from an SDL point of view, this mechanism puts Axiom 2 into action. Beneficiaries and other stakeholders become active co-creators of value instead of being passive recipients. It also illustrates how resource integration (Axiom 3) can proceed through synchronous joint activity rather than prior aggregation, with the shared representation serving as the medium through which diverse operant resources are combined.

4.5 Cross-boundary resource orchestration

Functioning as integrative infrastructures, DTs actively structure, coordinate, and recombine heterogeneous resources across organizational, lifecycle, and systemic boundaries (Meierhofer et al., 2021). They aggregate distributed data and models into a shared representation while coordinating resource flows and actor contributions within the ecosystem (Nguyen et al., 2024; Trizio et al., 2024), thereby promoting cross-lifecycle coordination and transparency (Martinelli et al., 2024). Shared value emerges through the coordinated contributions of multiple actors, enabling new services and business models (Ricci et al., 2021) and improving decision quality through integrated, context-specific information (Meierhofer et al., 2020). Taken together, the five mechanisms constitute an interconnected configuration: M1 establishes the continuously updated data foundation, M2 projects real-time states into alternative futures, M3 feeds operational outcomes back into the model, M4 opens the shared representation as a collaborative design space, and M5 extends these dynamics across organizational and lifecycle boundaries. From a SDL perspective, M5 provides the infrastructural precondition for service ecosystems in which resource integration (Axiom 3) and value co-creation (Axiom 2) extend beyond single organizations, coordinated through shared institutional arrangements (Axiom 5).

5 Digital Twins as Mediator of Structuration in Service Ecosystems

Drawing on the SDL and structuration-theoretical foundation from Section 2, this study conceptualizes how DTs facilitate value co-creation in service ecosystems. The duality of structure and actor practices serves as the analytical lens: institutional arrangements (Axiom 5) correspond to structure, while resource-integrating and service-exchanging practices (Axioms 1 and 3) reflect agency. The sociomaterial extension of structuration theory (Orlikowski, 2007) captures the constitutive role of technological artifacts in this recursive process. DTs are argued represent a particularly radical form of this entanglement by materializing structure into a persistent, shared, and manipulable digital representation, making the duality observable and accelerating its dynamics.

Five mechanisms emerge through which DTs mediate structuring in service ecosystems. Two of these operate along the conditioning dimension, linking structure to action. Real-time mirroring and synchronization (M1) render institutional arrangements visible and accessible, transforming distributed data into a dynamically usable resource that multiple actors can integrate simultaneously (Axiom 3). Simulative anticipation (M2) extends this logic into the temporal domain, enabling actors to construct, evaluate, and compare potential future states before committing resources. As a result, decision-making shifts from reactive responses toward more forward-looking assessments, introducing a prospective dimension to resource integration. Figure 3 illustrates these relationships.

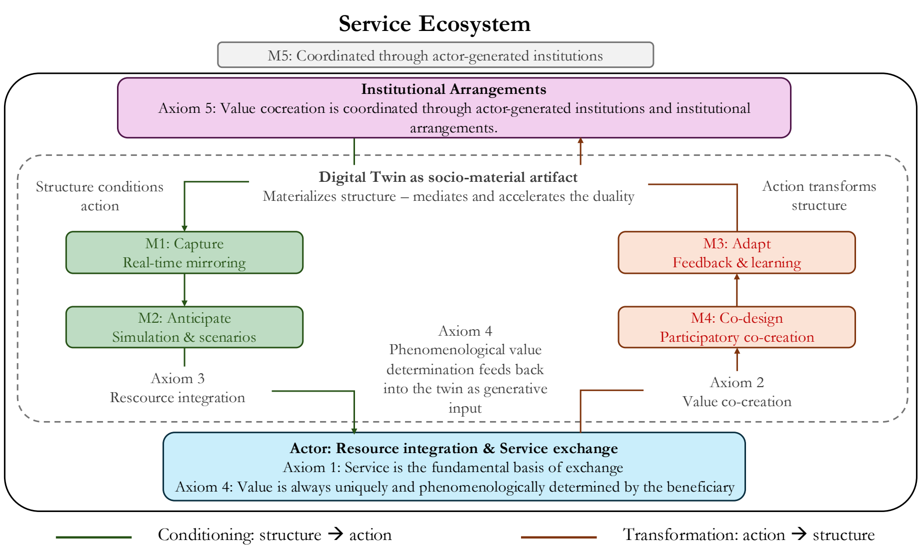

Figure 3: The digital twin as a socio-material mediator of structuration in service ecosystems
Source: Own

Two additional mechanisms operate along the transformative dimension. Feedback-driven adaptation (M3) establishes recursive learning loops through which operational data, user interactions, and service outcomes continuously reconfigure the structural conditions for subsequent action. Interactive co-creation (M4) enables multiple actors to jointly explore and iteratively refine solution designs within a shared digital representation, co-creating not only value but also the institutional arrangements coordinating future value creation (Axiom 2). Through M3 and M4, the beneficiary's phenomenological determination of value (Axiom 4) becomes operationally generative. Hence, experience-based assessments are not merely evaluative endpoints but transformative inputs that, mediated by the DT's feedback structures, reshape the institutional fabric of the ecosystem.

Finally, cross-boundary resource orchestration (M5) functions as an overarching mechanism that scales the structuring process beyond individual organizations by actively structuring, coordinating, and recombining heterogeneous resources across organizational, lifecycle, and system boundaries. This mechanism creates the infrastructural prerequisite for what Vargo & Lusch (2016) describe as service ecosystems, namely relatively self-contained and self-adapting systems of resource-integrating actors linked by shared institutional arrangements. It thereby extends the scope of the duality from the intra-organizational to the ecosystemic realm.

Overall, this conceptualization suggests that the DT is not merely a tool within an existing ecosystem but a sociomaterial artifact embedded in the structuring process. It materializes structure, renders the duality observable and actionable, and compresses Giddens' (1984) process of social reproduction into a near real-time, data-driven cycle, transforming value co-creation from being episodic and implicit into being continuous, explicit, and reflexively controlled.

6 Discussion & Conclusion

A systematic literature review of 53 articles and an SDL-oriented analysis identify five mechanisms derived from 20 second-order themes (see Figure 2), which are integrated into a conceptual framework grounded in SDL and structuration theory.

The results consolidate fragmented perspectives on DTs through the lens of SDL, extending prior work that treats DTs mainly as resources within service ecosystems.

While earlier studies remain largely case-specific (Meierhofer et al., 2021; Zarco, 2024), the developed framework synthesizes findings from diverse application contexts, including manufacturing, energy, and infrastructure, into a domain-independent set of mechanisms, thereby moving beyond case-specific accounts. By embedding technically described DT functionalities within the duality of structure and actor practises, the framework connects implementation-level descriptions with SDL´s value-oriented vocabulary. Adopting a structuration-theoretical perspective further reveals a generative dimension often overlooked: DTs not only enable resource integration but also generate, reinforce, and transform norms, rules, and practices. In this sense, DTs emerge as sociomaterial, structure-forming artifacts that actively shape value co-creation.

A key implication concerns the relationship between SDL axioms and the identified mechanisms. While the framework builds on resource integration, value determination, and institutional arrangements (Axioms 3–5), Axioms 1 and 2 remain underexplored. The predictive and autonomous capabilities of DTs may render beneficiaries more passive, however, can also empower actors as co-creators depending on how environments are designed. Future research should therefore examine how DTs reshape value determination.

This study has several limitations. DT implementations vary widely, and it cannot be fully ensured that all analyzed cases reflect core DT characteristics. In addition, DTs are often intertwined with other technologies, making it difficult to isolate a technological scope. This challenge was addressed by focusing on phenomena attributable to core DT capabilities. Moreover, SDL was not originally developed as a theory for a technological context, which required interpretive linking between mechanisms and SDL concepts. Methodologically, the coding process was conducted by a single researcher, which may introduce individual interpretive bias. To counteract this, SDL axioms were used as sensitizing devices to guide the coding process. The complete coding scheme is provided in an online appendix (link) to enable transparency.

Future studies can validate the identified relationships using approaches such as case study research. Questions of power asymmetries and governance remain open, particularly how control over DTs and data access shape actor relationships. The dynamic nature of service ecosystems also calls for longitudinal studies examining how these mechanisms evolve in response to technological and market developments.

In particular, future research could apply the proposed mechanisms in empirical settings to test their analytical utility and refine the boundaries between conceptually adjacent mechanisms such as M3 and M4. Additionally, configurational or process-oriented approaches could help formalize the interdependencies among the analytically distinct but mutually reinforcing mechanisms.
Overall, this study advances the understanding of DTs as both components of and influential elements within service ecosystems. By identifying DT-specific mechanisms and embedding them within the duality of structure and actor practises, it connects technical implementation with SDL´s value-oriented perspective.

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