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The static vs. dynamism paradox in value-driven design: a descriptive study of value management challenges in complex system design

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ABSTRACT: This study investigates the challenges of dynamic value integration in complex innovation projects. Difficulties stem not from a lack of willingness, but from a persistent lack of re-openability in design governance systems. This study identifies a triple closure mechanism that filters out evolving stakeholder values. The paper reframes value integration from a technical problem to a political-institutional process, arguing for an Adaptive Governance Infrastructure designed to manage the necessary tension between static and re-opening.

KEYWORDS: value-driven design, complex systems, project management

1. Introduction

The development of complex systems is a cornerstone of modern industry, directly shaping competitiveness and long-term success (Siyam et al., 2015). Such systems involve multiple stakeholders with diverse and often conflicting expectations, spanning technical, social, and environmental domains (Lalevée et al., 2021). In this context, value has emerged as a central construct, both as a driver of decision-making (Brosch & Sander, 2015) and as a guiding principle for engineering choices.

Despite this recognition, engineering practice continues to struggle with value integration. Traditional approaches have often reduced value to narrow economic terms, such as functionality divided by cost (Siyam et al., 2015) or the change in economic value of a work product (Siyam et al., 2015); a conception now widely recognized as deficient (Lavi & Reich, 2024). Value is now conceptualized as a system value to account for its inherently multi-dimensional nature, combining qualitative and quantitative aspects that are difficult to trace back to specific system features (Siyam et al., 2015). In this work, we adopt the definition of system value as "the system's holistic impact, encompassing the multi-domain effects on processes, environments, and stakeholders" (Lavi & Reich, 2024). The 'system value' thus represents a synthesized and emergent outcome of negotiations among diverse stakeholder values, while recognizing that its abstract nature may limit its reliability as a consistent measure.

A further challenge is that system value is not static. It evolves with design decisions, stakeholder interactions, and changes in the surrounding ecosystem (Bertoni et al., 2019; Lavi & Reich, 2024). As requirements shift and knowledge accumulates, the perceived value of a system may change dramatically over its lifecycle (Siyam et al., 2015). This tension is central: requirements are often the codified-but-static product of an initial value-to-decision process, placing them in direct conflict with the dynamic, evolving nature of value itself. Yet, most existing assessment models remain static, overlooking this dynamic behaviour (Bertoni, 2017; Machchhar et al., 2022).

The dynamic and context-dependent nature of value positions its evaluation as a wicked problem (Lavi & Reich, 2024), one that cannot be resolved with linear, deterministic processes such as those found in Lean Product Development (Siyam et al., 2015). This disconnect highlights a critical gap: while the literature acknowledges value's complexity, few empirical studies have systematically analysed the root causes of

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these practical barriers that prevent its effective integration, which is a critical inhibitor to maximizing value creation in evolving innovation projects.

This research undertakes a multi-faceted investigation into the challenges of integrating dynamic stakeholder values in evolving innovation projects. Our approach leverages a mixed-methods methodology, combining theoretical analysis with empirical investigations to address the research question: ***What are the main challenges regarding the dynamic integration of stakeholders' values in evolving innovation projects, and why do they persist?***

The contributions of this work are three-fold. First, it establishes a mixed-methods research design that enables the empirical identification and synthesis of three core axes of integration failure. Second, these findings are synthesized into a theoretical framework articulating three interconnected forms of closure (linguistic, decisional, and political) as the root cause of this failure. This framework explains the persistence of "bounded dynamism," a state where projects iterate on technical details but fail to metabolize evolving strategic value commitments. Third, the study's primary conceptual contribution is to reframe value integration: moving beyond a technical problem of optimization, it's redefined as a political-institutional process of negotiation that fundamentally requires an adaptive governance infrastructure.

2. Related concept

This section reviews the literature to establish the theoretical foundations of this study by justifying its three core hypotheses.

The literature shows that system value is a complex and multifaceted concept. It combines measurable technical metrics with qualitative, abstract indicators (Siyam et al., 2015). Its holistic and dynamic nature makes "value" a powerful construct, but also one that is inherently ambiguous (Lavi & Reich, 2024). This ambiguity is not only theoretical but also practical, creating difficulties in project operations and generating semantic instability that can affect the project's core vision. As a result, strategic goals may be interpreted differently across teams and stakeholders. This suggests a closure, where the absence of a shared language prevents values from becoming actionable. Therefore, it is essential to examine whether this ongoing semantic ambiguity acts as a main barrier to effective value integration.

The contested and evolving nature of value makes its integration difficult, as it seems unlikely to be resolved through purely technical or linear methods (Siyam et al., 2015). The literature highlights that, as shown by Lalevée et al. (2021), when stakeholders fail to reach a shared understanding of value, projects tend to collapse under pre-existing power dynamics and institutional hierarchies

In these scenarios, decision-making becomes guided more by authority than by consensus. This shifts the issue from a procedural challenge to a closure of project governance, where authority replaces genuine negotiation. Consequently, we must investigate whether these decisional barriers, power imbalances, and governance weaknesses act as key inhibitors of dynamic value integration.

A core tension exists between the dynamic nature of value and the static practices that prevail in engineering design. For reasons of control and simplicity, traditional approaches have long treated values as fixed parameters defined at the start of a project (Browning & Honour, 2008). While newer methodological clusters have emerged to explicitly manage value dynamics (Persehais et al., 2025), a persistent gap between theory and practice remains.

Even iterative approaches, such as Value Sensitive Design, are rarely applied iteratively; a recent review revealed an "alarming" lack of true iteration (Winkler & Spiekermann, 2021).

This closure is rooted in rigid governance systems that depend on fixed baselines for control (Machchhar et al., 2022). Such inflexibility leaves project systems poorly equipped to adapt, meaning late stakeholder involvement is seen as disruptions rather than opportunities. Hence, it's crucial to explore whether this structural inability to accommodate temporal changes constitutes a central barrier to dynamic value integration.

3. Methodology

To investigate the challenges of integrating dynamic stakeholder values, this research adopts a mixed-methods approach. It combines historical analysis, situated experimentation, semi-structured interviews, and empirical inquiry. This triangulation enables a multi-layered understanding of value-related tensions, covering both their temporal evolution and contemporary manifestations.

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As this research constitutes an exploratory descriptive study, the analysis is designed to identify and map underlying structural patterns rather than to produce a broad statistical generalization. Our research design relies on methodological triangulation: The survey serves to test the internal consistency of the qualitative finding (case study, interviews, serious game). We use Freidman test, which is appropriate to detect differences in rank-order within smaller expert samples.

The aim of this approach is to build a balanced and comprehensive dataset through complementary methods. The initial hypotheses were tested and validated for breadth using the quantitative survey/questionnaire (N=15) (3.1). These findings were subsequently deepened and confirmed by triangulating the results across our historical case study (3.2) and our situated case study (3.3), which provided objective observations of mechanisms. In addition, subjective insights and contextual nuances were captured through the qualitative interviews (3.1), combining the breadth of quantitative data with the depth of qualitative data to offer a fuller understanding.

The methodology is structured around three core hypotheses, which consolidate the findings from preliminary fieldwork and align with the three analytical axes of the study:

- Semantic instability, stemming from value ambiguity and vision divergence, prevents the consolidation of design intent and shared understanding—H1.
- Decisional barriers, including power asymmetries and the absence of adaptive governance, lead to selective and inequitable value integration determined by power rather than arbitration—H2.
- Temporal disruptions, caused by late stakeholder emergence interacting with rigid governance structures, prevent the system from adapting to new value propositions, converting them into systemic threats—H3.

3.1. Empirical Inquiry: interviews and questionnaires

The first component of the methodology aimed to capture the human and organizational dimensions of value integration in complex design projects. We conducted a qualitative and quantitative empirical inquiry, combining semi-structured interviews with a structured questionnaire.

A total of 9 semi-structured interviews were conducted with senior expert (average experience >10 years) involved in complex systems design and management. The interviewees **included project managers, systems engineers, and design leads** in sectors such as **railway, defence and space**. This diversity ensured a rich understanding of how value-related challenges are perceived and addressed in practice.

These interviews were analyzed using thematic coding, where transcripts were mapped against the three axes of closure to identify recurring organizational friction points. The qualitative data provided insights into the organizational and cognitive barriers to dynamic value integration.

To complement these insights, a structured questionnaire was distributed to a broader sample of practitioners (N=15) using a purposive sampling strategy to ensure alignment with the complex systems criteria. To test the statistical significance of our hypotheses, the data from the 5-point Likert scales was analysed using the Friedman test. This non-parametric approach allowed us to determine whether the perceived impact of semantic instability (H1), decisional barriers (H2), and temporal disruptions (H3) differed significantly across the expert population. This dual approach ensures that the identified 'Bounded Dynamism' is not merely an anecdotal observation but a statistically supported structural property of design governance.

3.2. Historical case study: the Aramis project

The second component of the methodology involves a retrospective analysis of the Aramis project, as documented by Bruno Latour (2002). This historical case offers a rich narrative of a failed innovation initiative in the public transportation sector. Its focus on a complex rail-based system makes it highly representative of the systems addressed in this research.

Aramis is particularly relevant due to its technical ambition and its tripartite decision-making structure. The project was shaped by three major entities: the French government, the RATP (Parisian transit authority), and the engineering consortium MATRA. Each wielding equivalent formal power but was driven by distinct institutional needs, convictions, and strategic agendas. This balance of power, with no single overriding authority, created a quintessential environment for observing the mechanisms of value negotiation (or their failure).

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The case's robustness is further anchored in Latour's rigorous sociological investigation. This work included over 50 stakeholder interviews and the analysis of 32 internal technical documents. This provides a solid empirical foundation for understanding how value dynamics unfolded. Longitudinal perspective allows us to trace the interaction of stakeholder expectations, technological ambitions, and socio-political forces. It shows how the absence of effective mechanisms to negotiate and realign values led to the project's paralysis and abandonment.

3.3. Situated case study: serious game simulation

To ensure the ecological validity of our findings, we employed a situated experimentation approach via a Serious Game. This method was selected to bypass the *social desirability bias* of interviews and observe real-time negotiations of the *static vs. dynamism paradox*. This simulation placed participants in a controlled, realistic design scenario. They were tasked with navigating stakeholder values using contemporary tools and methods.

The participant group consisted of five professionals from the railway sector. They held diverse roles, including engineers, PhD holders, and training managers. Each participant had over five years of experience and a comprehensive understanding of the sector's technical, organizational, operational and strategic dimensions. Their expertise enabled them to interpret stakeholder roles with realism and exhibit representative behaviours.

The serious game scenario was designed to reflect the complexity of modern innovation projects. It incorporated multiple stakeholder perspectives, evolving requirements, and conflicting value priorities. The simulation used a fictitious pilot project to deploy a multi-technology supervision system for railway infrastructure, specifically under extreme environmental conditions. The 5-hour session, was structured around realistic constraints and dilemmas (operational vetoes, budget cuts, regulatory conflicts, restrictions, and technological failures). Participants were initially provided with a fixed strategic value proposition. Mid-way through, *Disruption Cards* were introduced to force a re-negotiation. Data was captured through non-participant observation and a thematic analysis of the design artifacts produced during the session, specifically looking for instances of *Decisional Closure* where technical constraints overrode strategic value re-evaluation.

4. Findings

This section presents the main findings of the study, organized around three analytical axes corresponding to our hypothesis. Each axis integrates and synthesizes evidence from the mixed method. The findings confirm the persistence of value-related tensions and reveal their interaction across cognitive, organizational, and temporal dimensions.

4.1. Semantic instability and vision misalignment (H1)

This axis investigates how semantic ambiguity and vision divergence jointly destabilize value integration. This mechanism was observable across all four data sources.

The survey provides quantitative evidence of this mechanism. Results indicate that experts generally agree with the hypothesis that value ambiguity and vision divergence significantly hinder value integration ($M = 3.84$). The low standard deviation ($SD = 0.51$) further suggests a strong convergence of perception among experts, pointing to a shared recognition of these factors as persistent barriers. This directional signal provides the empirical foundation for the mechanistic analysis of semantic friction developed in the following qualitative case studies.

The historical case of Aramis demonstrates this mechanism at a systemic scale. The project juxtaposed two conflicting value regimes: individual autonomy and collective safety (automobile vs railway logic). It failed to establish a unifying interpretive frame. The vision wasn't clarified. Instead, it was periodically reasserted in its original abstract form. This allowed stakeholders to continue projecting divergent meanings onto it. As a result, the "vision" operated as a floating signifier. It rhetorically mobilizing support but failed to stabilize design choices. The instability was not accidental but self-reinforcing. Each stakeholder preserved ambiguity as a negotiation space rather than risking explicit resolution.

The serious game provided operational evidence of this mechanism. Ambiguity materialized as a "conflict of translation". The same terms ("robust", "adaptable", "efficient") were used by different participants with incompatible meanings. Convergence was obtained through successive concessions, not shared interpretation. This functioned as a negotiated workaround rather than true alignment.

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Furthermore, the ambiguity did not decrease over time. Observations note the absence of a learning loop, as earlier clarifications were repeatedly reopened when new constraints appeared. This confirms that ambiguity is structurally persistent when no shared referential exists.

This same challenge was a primary theme in the semi-structured interviews. Interviewees frequently described the absence of a shared value language. They noted that even foundational terms lacked stable meaning. As one participant explained:

> *"Just the word 'project'—has different meanings depending on who you talk to." (E1)*

This instability does not stem from missing information. It arises from coexisting interpretive frameworks. Another interviewee highlighted the difficulty of translating high-level aspirations into design-relevant commitments:

> *"Being more sustainable is complex to translate directly. We often have to reformulate it as a question." (E5)*

Overall, the findings indicate that semantic instability does not fade with time or maturity. In the absence of explicit meta-governance of meaning, ambiguity remains functional for negotiation. However, it's detrimental for integration, preventing values from becoming actionable design criteria.

4.2. Decision barriers to equitable integration (H2)

This second axis investigates how a lack of consideration of asymmetric influence interacts with weak or non-adaptive governance structures to create decision barriers.

The survey provides quantitative support for the *Decisional Barrier axis*. The aggregated score ($M = 3.42$, $SD = 0.66$) lies slightly above the neutral midpoint, indicating a moderate tendency among respondents to agree that power asymmetries and governance gaps act as inhibitors to equitable value integration. The moderate standard deviation suggests some diversity of perception, reflecting that while the issue is generally recognized, its salience varies across expert profiles. This quantitative tendency offers an initial indication of how decision dynamics may constrain value alignment—an interpretation further developed in the qualitative analyses below.

The Aramis case reveals a longitudinal mechanism of exclusion. In the absence of explicit governance for value arbitration, technical legitimacy acted as a silent filter. Sociopolitical and user-oriented concerns were not openly rejected. Instead, they struggled to find operational traction. These values were acknowledged discursively, appearing in reports and public statements. Yet, they remained peripheral to design decisions. This marginalization did not stem from direct opposition. It arose from a limited capacity to translate such concerns into the dominant language of engineering design. A telling example is the 1983 Sofres study (Latour, 2002). It offered detailed insights into user perceptions, including anxiety about confinement and distrust of automation. Despite their relevance, its findings did not influence the evolution of the system. This suggests that user-oriented values remain outside the actionable scope of the project, even when formally documented.

The serious game dynamically reproduced this governance structure. It demonstrated how technical authority pre-emptively frames deliberation by embedding feasibility constraints. The simulation revealed that stakeholder negotiations were constrained by pre-existing hierarchical priorities. This limited the range of possible outcomes. The game functioned as an accelerated microcosm of the real-world power relations, illustrating how formal processes can perpetuate existing.

Interviews confirmed this finding: while value negotiation is formally open, it's materially constrained by the position and institutional authority of specific stakeholders. Influence is exercised through control of what becomes binding rather than through the argumentative strength of a value claim. Interviewees explicitly described this unequal leverage:

> *"In the end, when a decision is made, it's our position that prevails . . . " (E4)*

A similar pattern emerges in governance. While formal processes exist, they rarely function as mechanisms for resolving value conflicts. Instead, they impose procedural rigidity without addressing the underlying legitimacy of decisions. As one participant observed:

> *"They're not trying to solve the problem—they're trying to satisfy their boss." (E3)*

This dynamic reveals how middle management priorities distort decision-making. It reduces governance to a performative exercise rather than a tool for meaningful arbitration. Another interviewee highlighted the disconnect between operational management and executive leadership:

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"So then you get this gap between operational management [. . .] and top-level leadership. And you end up with improbable conversations and discussions." (E6)

This illustrates how hierarchical misalignment, where strategic intentions diverge from operational realities leads to incoherent decision-making. Such gaps reinforce decision asymmetries, hindering the translation of stakeholder values into coherent design choices. Overall, these findings indicate that governance gaps do not merely weaken value integration; they create a decisional vacuum where power substitutes for arbitration. When arbitration is absent, framing precedes collaboration, and power determines which values become designable.

4.3. Temporal disruptions and stakeholder emergence (H3)

This axis investigates how late stakeholder emergence interacts with absent adaptive governance to produce temporal ruptures.

Quantitative results for the Temporal Disruption axis indicate a moderate level of agreement ($M = 3.30$, $SD = 0.67$). The mean value, slightly above the neutral midpoint, suggests that late stakeholder emergence is generally perceived as a challenge to value integration, though not uniformly across respondents. The relatively higher standard deviation compared to the other two axes reflects greater variability in how practitioners assess the impact of temporal factors. This dispersion points to differentiated experiences with timing and participation dynamics, which are further examined through the qualitative analyses below.

The historical case of Aramis exhibits this temporal mechanism over a longer horizon. The 1983 Sofres study (Latour, 2002), documented user anxiety regarding confinement and automation. It arrived too late to influence the technical framing. Similarly, the 1986 political turnover also introduced a new strategic orientation. This new strategy could no longer be absorbed without undoing earlier commitments. The project did not reject user values; it simply could no longer accommodate them.

The serious game reproduced this dynamic within a controlled setting. Two hours into the session, the introduction of the Minister of Transport triggered an immediate reconfiguration of influence structures. This occurred after an initial stabilization of value allocations. The decision weight of the Railway Infrastructure Manager highly declined (from 53% to 30%). Meanwhile, the coalition formed by the Region, the Operator, and the Minister increased its weight (from 37% to 53%). This shift did not result from deliberation but from institutional gravity. The symbolic authority of a high-level stakeholder displaced previously stabilized commitments.

At the operational level, available governance instruments proved unable to absorb the shock. Tools like the requirements log and justification matrix were activated only after the rupture. They served primarily as mechanisms of post hoc documentation, rather than anticipatory arbitration. The governance framework ceased to function as an adaptive structure. It became a space for managing the aftermath of disruption.

This pattern was described by interviewees as recurrent and structurally embedded. Across all data sources, the timing of stakeholder entry was the primary determinant of their effective influence, not the content of their demands. When new stakeholders appeared after technical or architectural commitments had already crystalized, their values could not be integrated. Doing so would require reopening foundational decisions, resulting in systemic destabilization rather than adjustment. One participant noted the enforcement power of late institutional intervention:

"I had a wall of lawyers who killed the project before even talking to me." (E3)

This was not attributed to disagreement over purpose, but to temporal misalignment. The intervention occurred only once design was too mature to be renegotiated. Another interviewee emphasized the cyclical instability created by turnover:

"Every two years, people change. That means new policies, new visions. We stop one project, then two years later someone says, 'Hey, what if we did this?'—but we already tried that ten years ago." (E2)

Overall, the findings demonstrate that stakeholder emergence is a structural property of complex sociotechnical systems, not an episodic disturbance. Explicit temporal governance is needed. Such governance would provide mechanisms to reopen design commitments when new stakeholders appear. In its absence, time itself becomes a gatekeeper. Early values become embedded by design; late values arrive as threats. As a result, instability is not caused by the late emergence of stakeholders. It's caused by the disruptive impact their values have on a system that's unable to remain permeable once closure has begun.

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5. Discussion

The findings reveal a core challenge. The difficulties of dynamic value integration do not originate from a lack of willingness or analytical capability. Instead, they stem from deeply embedded structural properties of design governance. Across the three axes, a common mechanism emerges. Values do not fail due to poor expression or contestation. They fail because the sociotechnical system is not designed to remain re-openable over time. Temporal, semantic, and decisional closure progressively reduce the permeability of the design space. They convert early commitments into infrastructural facts and relegate later values to frictional noise.

5.1. The tripartite nature of the challenge: linguistic, decisional, and political

The persistence of integration challenges can be attributed to three interconnected forms of closure.

- ***Linguistic Closure:*** This describes the system's failure to translate or identify certain forms of value. Our findings reveal a recurring difficulty in translating qualitative values. This is especially true for user-oriented or abstract ethical concerns. This difficulty arises because these values carry significant systemic impacts. These impacts are not easily captured by the dominant, quantitative language of engineering design (i.e., performance, cost, technical feasibility). This linguistic asymmetry, evident in the "conflict of translation" in the serious game. It functions as a powerful epistemic filter. It creates a hierarchy of knowledge that privileges the quantitative and technical over the experiential and political. Consequently, values that cannot be "operationalized" are effectively excluded from design decisions, even when formally acknowledged.
- ***Decisional Closure:*** This refers to the process by which initial design decisions become irreversible. Stabilization is a necessary function for project coordination. However, this mechanism creates a powerful path dependency, as demonstrated in the Aramis case. This closure is not a late-stage effect. It's a silent outcome of early framing decisions. These early representations carry implicit value hierarchies that quickly become naturalized as "technical constraints." As evidenced by the temporal disruptions in the serious game and interviews (E2, E3), time itself becomes a gatekeeper. The timing of a value's appearance, rather than its merit, determines its influence. This is because the system lacks mechanisms to reopen and re-legitimize these foundational commitments.
- ***Political Closure:*** This mechanism is activated by the failure of the other two. In the absence of a shared language (Linguistic Closure) or the ability to reopen past decisions (Decisional Closure). This creates a governance vacuum, which, as our H2 findings predict, this vacuum is filled by power dynamics rather than legitimate processes. Interviewees (E4, E6) and the serious game dynamics confirmed this. Governance mechanisms are often optimized for control, stability, and accountability. They are not optimized for learning, responsiveness, and adaptation. Consequently, when new values emerge, the system lacks the procedural space to host their re-evaluation. The "governance" observed is not adaptive, but reactive. It's a performative exercise that manages disruption rather than anticipates and integrates change.

5.2. Beyond "Bounded Dynamism": the illusion of iteration

The "triple closure" mechanism described above does not result in a completely static system. Rather in an architecture of "bounded dynamism." The empirical material shows that while stakeholder values do evolve (Bertoni et al., 2019; Lavi & Reich, 2024), the project system lacks the mechanisms to re-legitimize foundational commitments considering this new context.

This creates an "illusion of iteration." This illusion arises from a common confusion. The observable, high-frequency activity of "agile" development is mistaken for genuine strategic adaptability. What is often theorized in design literature as "iterative" or "adaptive" governance is, in practice, something different. It's a form of incrementalism applied only to peripheral technical artefacts. It's an iteration on means (i.e., finding a more efficient technical solution). It's not an iteration on ends (i.e., questioning or re-evaluating the strategic purpose). The system, therefore, becomes highly adept at optimizing solutions for a fixed and "locked-in" set of strategic values. Meanwhile the "triple closure" mechanisms prevent any genuine re-negotiation of those values themselves.

Consequently, the strategic value commitments are not subject to iteration. Due to the "triple closure", they are effectively "bounded" and protected from re-evaluation. The system can adapt at the margins

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(technical changes). But it cannot absorb new values that challenge its core. Doing so would require reopening foundational decisions—a costly and destabilizing prospect. It would also require navigating the political challenges that emerge in the absence of legitimate adaptive governance. This strategic lock-in is particularly acute in the sectors we studied (railway, defence, space). In these contexts, foundational commitments are heavily dependent on external forces. These include political decisions, long-term public financing, and shifting regulatory norms. The core value proposition is thus "locked-in" by these institutional forces. It's rendered non-negotiable at the project level. This creates the central paradox: dynamism becomes a purely theoretical or peripheral technical activity, while strategic fixity becomes the operational reality. This structural condition, rather than a failure of will, explains the persistent "alarming" gap (Winkler & Spiekermann, 2021) between design theory and design practice.

5.3. Implications: from technical problem to political process

Taken together, these insights compel a fundamental reframing of the value integration challenge. The findings demonstrate that this challenge is not, as traditionally assumed, a technical problem of optimization and it's not merely a technical problem of translation. As the Aramis case demonstrates, even successfully translated user-centric data was ignored due to governance failures. Instead, the "triple closure" reveals the challenge to be a political-institutional process of negotiation.

This perspective requires a theoretical shift. Values are not stable, pre-existing inputs to be discovered and optimized. Instead, they are dynamic, contested, and socially "situated" constructs. They emerge through the design process itself. They are mediated by the dominant language of the project. They are shaped by institutional structures. And they are filtered by early decisions.

The primary implication concerns the governance. Current models are optimized to govern stability and control. They must be replaced by models designed to govern adaptability. The findings therefore compel a reorientation of design practice toward the creation of an Adaptive Governance Infrastructure. The purpose of such an infrastructure is not to prevent closure, which is necessary for coordination. Its purpose is to explicitly design and manage the process of re-opening. This requires:

- **Legitimate Spaces for Arbitration:** Mechanisms to resolve value conflicts based on negotiated agreement, not latent power dynamics.
- **Protocols for Translation:** Processes that give explicit standing to non-technical, qualitative, or user-centric knowledge.
- **Explicit Re-opening Mechanisms:** Triggers and processes to re-evaluate foundational commitments when new stakeholders or contextual shifts emerge.

Such an infrastructure, a system deliberately structured to evolve alongside the project and its ecosystem, is the necessary precondition for realizing dynamic value integration in practice.

In this regard, approaches such as EVOKE (Bertoni et al., 2018) offer a promising methodological pathway. By providing a structured language to translate abstract values into actionable value criteria through value creation strategy (VCS) and Value Drivers (VDs), EVOKE directly mitigates Linguistic Closure. Furthermore, its exploratory nature actively limits premature decisional fixation, while its ability to facilitate design selection based on varying application contexts provides a technical foundation for legitimate arbitration, thereby addressing the systemic root causes of Political Closure.

5.4. Limitations and future work

This study presents several limitations which, in turn, delineate clear pathways for future research.

A primary limitation is the study's linguistic and cultural grounding. All interviews and questionnaires were conducted exclusively in French, and the case studies are anchored in a specific national institutional context. This limitation is compounded by the methodological diversity among respondents (e.g., some operating within design thinking or agile frameworks, often in FabLab contexts). It would be interesting to investigate whether this variance can partly explain the heterogeneity of the results. However, this context is not insular, as several participants work within multinational corporations requiring international collaboration or on products destined for a global market. Nonetheless, the primary context, often characterized by state-led, "dirigiste" approaches to large-scale engineering. This setting may foster particular models of governance and power dynamics that are not universal. This limits the immediate generalizability of the findings. Future work must determine how different institutional, political, and cultural settings shape the processes of value negotiation and closure.

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A second limitation is the reliance on a retrospective historical case. The analysis of the Aramis project is mediated through the work of Latour (2002). To mitigate the bias of this specific sociological (ANT) lens, our analysis prioritized the extensive primary source materials archived within Latour's study. These include technical documentation and meeting reports. Nonetheless, a constraint of retrospective data remains, both here case and in our interviews. To fully mitigate this, future research should prioritize longitudinal, real-time ethnographic studies. Such work is necessary to trace the dynamic interplay of values and governance as it unfolds, capturing closure mechanisms in situ.

A third methodological limitation lies in the exploratory nature of the serious game simulation (N=5) and the small sample size of the quantitative survey (N=15). While highly effective for illustrating mechanisms and triangulating qualitative findings, these components are not intended for broad statistical generalization. Notably, the quantitative analysis of the survey data did not identify any sector-specific effects (railway, defence, or space). The statistical significance found in our FRIEDMAN test ($p=0.0004$), while valid for this sample, must be interpreted with caution. It serves primarily to validate the internal structure of the qualitative findings rather than to make a generalizable claim about the entire population of engineering practitioners. The "Adaptive Governance Infrastructure" proposed in our discussion remains a theoretical construct. Future work should focus on designing, implementing, and testing of these proposed governance mechanisms within live innovation projects.

6. Conclusions

This research investigated the persistent challenges of dynamically integrating stakeholder values within complex innovation projects. Our findings reveal a structural explanation: the core challenge lies in the fundamental lack of re-openability built into the sociotechnical systems of design governance.

Through the analysis of our cases, we have identified a triple closure mechanism (linguistic, decisional, and political). This mechanism systematically filters out values that emerge late, are expressed ambiguously, or cannot be translated into the dominant technical lexicon. We find that this closure is not a failure of intention. It's an unintended consequence of a system optimized for stability and control, rather than for adaptability and inclusion. The resulting "bounded dynamism"—where technical details are iterated but strategic values are fixed—explains why the persistent gap between the theory and practice of value integration.

The primary theoretical contribution of this work is to reframe value integration. We move it from a technical problem of optimization to a political-institutional process of negotiation. This aligns with and extends a growing recognition in design science (e.g. (Lavi & Reich, 2024)). This perspective holds that conceiving of system value requires a holistic, multi-domain perspective that treats design as an inherently normative and strategic practice.

Ultimately, this study argues that the path toward more responsive and responsible innovation lies not in perfecting value-identification tools. It lies in reconfiguring how innovation is governed. This requires new institutional mechanisms capable of supporting dynamic value integration. Rather than inventing these mechanisms from scratch, we propose a pragmatic approach. We may build upon the complementary strengths of existing methodological clusters identified in prior work (Persehais et al., 2025). The core challenge is to strategically hybridize and activate approaches (such as the Iterative Values Design Hub or the Holistic Values Visualization Hub). These are already designed to handle fluctuating, multi-criteria values. This enables a governance infrastructure that can sustainably manage the tension between the necessary fixation and the essential.

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