

Managing Paradoxical Tensions in the Implementation of Explainable AI for Product Innovation

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Abstract—This study investigates how organizations manage tensions arising during the implementation of Explainable Artificial Intelligence (XAI) in product innovation. XAI emerged as a promising technology to address some of the complexities of the product innovation process in organizations. However, while XAI research has advanced technically, little is known about how the technology reshapes organizational routines, professional interpretation of algorithmic outputs, and the management of human-AI tensions. Using a qualitative case study of a global confectionery manufacturer, we examine the introduction of an XAI-based solution through participatory action research and paradox theory. We identify four persistent tensions: automation versus human judgment, transparency versus complexity, speed versus accuracy, and standardization versus customization. Rather than resolving these contradictions, the organization managed them through dynamic both/and strategies that supported human-AI collaboration. Our findings extend paradox theory to XAI-enabled innovation and contribute to digital transformation literature by showing how explainability facilitates knowledge articulation, organizational learning, and effective system adoption. The study offers practical insights for designing XAI systems that complement human expertise in complex innovation environments.

Keywords—product innovation, explainable AI, paradoxical tensions

I. INTRODUCTION

In today's hypercompetitive markets, companies face unprecedented challenges in product innovation, particularly in complex information domains where decisions involve numerous interdependent variables [1, 2, 3]. In sectors like food manufacturing, organizations must balance ingredient interactions, process parameters, regulatory constraints, and consumer preferences, each influencing product outcomes in intricate ways. Traditional innovation approaches, often based on resource-intensive and trial-and-error methods, increasingly struggle to deliver the required speed, efficiency, and sustainability [4]. Explainable Artificial Intelligence (XAI) offers a potential solution by enhancing predictive capabilities while maintaining transparency and accountability [5].

Technical research on XAI has progressed rapidly [6], however we know little about how these systems reshape organizational practices. Specifically, there is limited insight into how XAI interacts with established innovation routines and how organizations manage resulting tensions. Prior studies have identified contradictions in digital transformation, such as stability versus change and control versus flexibility [7], but tensions specific to XAI adoption

remain underexplored. This study addresses this gap by asking: How do organizations manage the paradoxical tensions that emerge during the implementation of Explainable AI in product development processes?

To address this question, we employed a qualitative case study methodology [8] combined with a participatory action research (PAR) approach [9]. Our investigation focused on a global confectionery company introducing an XAI-based solution. We developed our study and analyzed findings through the theoretical lens of the paradoxical tensions, which conceptualizes organizational contradictions not as problems to be resolved but as enduring contradictions to be managed [10, 11]. This perspective is particularly well-suited to our research question, as AI implementations inherently generate competing demands that defy binary resolution.

Our findings identify four key paradoxical tensions: automation versus human judgment, transparency versus complexity, speed versus accuracy, and standardization versus customization. We show that successful implementation depends on embracing and managing these tensions through mechanisms including feedback loops integrating expert knowledge with algorithmic output and interface features clarifying AI reasoning. This study contributes to innovation management literature by extending the paradox perspective to XAI-enabled product development. For practitioners, our findings offer a framework for implementing XAI solutions that complement rather than replace human expertise.

The remainder of the paper is organized as follows. Section II reviews literature on innovation, XAI, and paradoxes in technology implementation. Section III outlines the research methodology. Section IV presents the case findings and the four identified tensions. Section V discusses implications, limitations, and future research directions.

II. LITERATURE REVIEW

A. Innovation Processes: Complexity and Challenges

Product innovation is essential for maintaining competitiveness in dynamic markets. Unlike product incremental improvements, innovation involves developing new offerings that generate customer value and strengthen organizational capabilities [1]. In manufacturing, this process is particularly complex due to interdependencies among material properties, production parameters, regulatory requirements, and market demands [2, 12]. These interdependencies create a "high-dimensional design space" where changes to one parameter can cascade throughout the system, complicating prediction and control [3].

The innovation process typically unfolds through iterative cycles of formulation, testing, and refinement, each generating knowledge that reduces uncertainty [4]. However, this approach faces structural challenges: physical experimentation is resource-intensive [12], much knowledge is tacit and difficult to transfer [13], and expert decision-making may suffer from cognitive biases [14].

External pressures compound these internal challenges. Accelerating product lifecycles demand shorter time-to-market, while global competition increases needs for differentiation and local adaptation [15]. Regulatory constraints, particularly in sectors such as food, pharmaceuticals, and chemicals, further limit viable options [16]. Supply chain volatility, exacerbated by geopolitical tensions, climate events, and public health crises, adds uncertainty around material availability and cost [17]. Together, these pressures create an environment where traditional trial-and-error approaches struggle to meet expectations for speed, efficiency, and flexibility.

B. Artificial Intelligence and Explainable AI in Innovation

Artificial Intelligence (AI) has emerged as a promising solution for managing innovation complexity. AI systems can process vast data volumes, identify patterns, and generate predictions beyond human cognitive capacity [18]. In product development, AI supports materials discovery, formulation optimization, process parameter prediction, and quality control [19]. These capabilities help organizations overcome resource limitations, knowledge fragmentation, and cognitive constraints of traditional approaches.

Yet AI integration into organizational processes introduces new challenges, particularly around algorithmic decision interpretability. High-performing models like deep neural networks often operate as "black boxes" with opaque internal logic [20]. This opacity undermines trust and limits adoption, especially where safety, accountability, and collaborative decision-making are critical [21]. In response, Explainable AI has emerged to enhance transparency and interpretability [5].

XAI methods vary in design: some use inherently interpretable models like decision trees that trade accuracy for clarity [22], while others apply post-hoc techniques to explain complex system outputs [23]. Explanations may include feature rankings, counterfactual examples, or natural language descriptions [21]. In innovation contexts, XAI can combine predictive performance with domain knowledge, enabling more effective human-AI collaboration [6].

Despite technical advances, research on XAI's organizational implications remains limited. Most studies focus on technical contributions, neglecting how XAI systems reshape work practices, decision-making routines, or knowledge flows [6]. Research lacks empirical insights into how professionals interpret algorithmic explanations, integrate these systems into innovation processes, and evolve human-AI relationships in practice. These gaps are especially relevant in knowledge-intensive domains where success depends on alignment with professional identities, organizational cultures, and established routines [24].

C. Paradoxical Tensions in Technology-Mediated Innovation

The paradox perspective offers a valuable lens for understanding tensions emerging when organizations

implement new technologies. Smith and Lewis [10] define paradoxes as "contradictory yet interrelated elements that exist simultaneously and persist over time" (p. 382). Unlike dilemmas implying mutually exclusive choices, paradoxes involve essential, ongoing demands. Organizations cannot resolve these tensions through one-time decisions; instead, they must manage them continuously [11].

Smith and Lewis [10] identify four core paradox categories: learning (old vs. new knowledge), belonging (individual vs. collective identities), organizing (control vs. flexibility), and performing (multiple goals and stakeholder expectations). These provide a foundation for analyzing tensions in technology adoption and innovation.

Paradoxical tensions are particularly relevant in digital transformation, where new technologies disrupt existing routines. Research identifies tensions such as stability versus change and control versus flexibility [25], as well as innovation versus standardization and experimentation versus stability [7]. These tensions evolve over time, shaping transformation journeys. AI introduction, especially explainable AI, adds new contradictions. Raisch and Krakowski [26] highlight challenges balancing algorithmic capabilities with human judgment, influencing task structure, authority, and collaboration. Von Krogh [27] emphasizes tension between performance pursuit and needs for interpretability and trust in knowledge-intensive settings.

The paradox perspective suggests organizations should adopt both/and strategies to manage XAI's competing demands. Effective implementation of technology relies on a dynamic equilibrium model where organizational sustainability depends on embracing contradictions and balancing them through both defensive mechanisms (separating conflicting elements) and active mechanisms (engaging paradox through integrative structures and capabilities). Exploring organizational responses to XAI-driven tensions offers insights into technology-mediated innovation and effective human-AI collaboration development.

III. METHODOLOGY

This study adopts a qualitative research design based on single-case study methodology [8], combined with participatory action research elements [9]. This approach suits our aim of understanding how organizations manage paradoxical tensions during XAI implementation in product innovation. Case studies are appropriate for "how questions" addressing complex, contemporary phenomena where boundaries between phenomenon and context blur [8]. The participatory component enabled close engagement with the case organization, providing real-time access to decision-making, practices, and tensions. Following PAR principles, researchers acted as active participants in the XAI system design and integration but collected and analyzed data with an objective approach, fostering mutual learning between researchers and practitioners.

The empirical setting for this study is SweetCo, a global confectionery manufacturer known for innovation orientation and decentralized product development processes. The company partnered with AISmart, a technology firm specializing in AI solutions, to transform the products' formulation process using an XAI tool called "Maia." The study was conducted between September 2023 and December 2024 and focused on the implementation process and its

implications for knowledge work, organizational routines, and innovation dynamics.

Data collection was multi-sourced, including semi-structured interviews, meeting observations, and internal documentation. The interview protocol explored participants' XAI experiences, work practice shifts, and emerging tensions. We conducted 21 interviews with key stakeholders: Head of Innovation, R&D specialists, formulation experts, project managers, and digital transformation leads from SweetCo, plus AISmart implementation team members. Interviews were recorded, transcribed, and anonymized. We also carried out non-participant observation of over 20 project meetings (in-person and online), focusing on design decisions, user feedback, and strategic planning. Field notes and internal documents (presentations, plans, training materials) complemented the dataset.

Data analysis followed an abductive logic [28], iterating between empirical data and theoretical concepts. Coding was carried out in three main stages. In the first phase, open coding was used to identify key activities, perceptions, and decision points in the implementation process. In the second phase, axial coding helped identify relationships between categories, with a particular focus on organizational tensions. Finally, in the third phase, selective coding and theoretical mapping were used to link empirical patterns to the conceptual framework of paradoxical tensions [10]. Coding and interpretation were discussed regularly among the research team to ensure consistency and critical reflection.

The participatory nature of the research provided unique insights but also raised concerns about objectivity. To address this, we adopted several strategies to ensure methodological rigour. First, we maintained a reflexive research journal throughout the project, documenting assumptions, interpretations, and the evolving role of the researchers in the field. Second, we triangulated data sources - interviews, observations, and documents - to cross-validate emerging interpretations. Third, data coding and theme development involved multiple researchers, which allowed for independent verification and reduced the risk of individual bias. Finally, we were transparent with project partners about our dual role as contributors to and analysts of the implementation process. This openness supported trust and enabled access without compromising the scientific integrity of the research.

IV. RESULTS

XAI incorporation into SweetCo's formulation process revealed how advanced digital technologies transform product development while generating new organizational tensions. Rather than resolving tensions through straightforward trade-offs, SweetCo developed dynamic both/and responses maintaining productive balance across competing demands. We present our findings on the case context and four key tensions, followed by analysis of how SweetCo handled these contradictory yet interrelated demands.

A. The Case Study: SweetCo Implementation of XAI in Product Development

SweetCo, one of the world's largest confectionery manufacturers, operates in over a hundred countries with a decentralized model balancing global presence with local market responsiveness. Despite its innovation-oriented culture, the company faced significant product development challenges. Formulation processes required managing

numerous variables simultaneously, ingredient interactions, processing parameters, regulations, and consumer preferences.

Traditional formulation approaches relied heavily on expert knowledge and resource-intensive experimentation, with R&D teams typically conducting approximately 150 physical experiments before approving new products. As one R&D manager explained:

"The driver was mainly the optimization of time-to-market processes, fundamentally the idea of also looking for a KPI that could correspond to a possible return on investment, which is a bit the main driver that moves company choices in general nowadays."

To address these challenges, SweetCo partnered with AISmart to implement an XAI solution in its formulation process. This system integrated three components: Explorer (historical visualization), Simulator (property prediction), and Explainer (key driver interpretation). Implementation occurred in two phases: initial proof of concept followed by a refined web-based application designed for enhanced human-machine collaboration.

B. Managing Paradoxical Tensions in XAI Implementation

Building on established theoretical frameworks, we identified four paradoxical tensions that emerged during the implementation of Maia at SweetCo. These tensions are not isolated project challenges but reflect broader organizational paradoxes described in prior literature. The automation–augmentation paradox [26] manifested in the tension between leveraging XAI algorithmic efficiency and preserving human creativity and professional judgment. The learning paradox appeared as SweetCo sought to reconcile the use of sophisticated, high-performing models with the need for transparency and interpretability to support knowledge sharing and validation [23]. A performing paradox became evident in the push to accelerate product development through virtual experimentation while still ensuring product quality through physical testing, mirroring the exploration–exploitation dilemma [29]. Finally, an organizing paradox arose in the need to standardize the use of AI models across the company for consistency, while also allowing local customization to meet market-specific and regulatory requirements, echoing global and local tensions found in multinational operations.

These tensions evolved throughout implementation, requiring dynamic responses and continuous adaptation. Tensions are summarized below and elaborated in the following sections:

1. **Automation vs. Human Judgment:** The tension between algorithmic efficiency and human creativity/intuition
2. **Transparency vs. Complexity:** The tension between sophisticated models and interpretable outputs
3. **Speed vs. Accuracy:** The tension between accelerating development and ensuring product quality
4. **Standardization vs. Customization:** The tension between consistent approaches and adaptation to specific contexts

Below we summarize how SweetCo managed these contradictory demands.

Tension 1: Automation vs. Human Judgment

The tension between automation and human judgment emerged as a central challenge. While the XAI solution offered rapid simulation capabilities exceeding human cognitive limitations, product development remained a creative process requiring sensory evaluation and professional judgment that couldn't be fully automated.

Initially, some R&D team members expressed concerns about potential expertise displacement. As one formulation specialist noted:

"The model gives us a recipe, but it's just a starting point. We still need to evaluate whether it makes sense from a technical and sensorial point of view."

Rather than positioning Maia as replacing human expertise, SweetCo integrated the XAI system throughout the innovation process, creating iterative feedback loops between human experts and AI. As the Head of Innovation explained:

"Ideally, our work always involves a phase of ideation, a phase of physical testing, preparation of the prototype, and analysis of the prototype itself, and evaluation of what has been done in the laboratory phase, before going to the industrial phase. With the XAI algorithm, we begin to see that before starting the process of, for example, testing, I use the model and basically I ask myself a few more questions."

This approach preserved human judgment while leveraging AI computational capabilities, transforming potential competition into productive collaboration.

Tension 2: Transparency vs. Complexity

The second tension involved balancing model sophistication with interpretability. Complex models offered greater predictive power but were inherently harder to explain, yet transparency was essential for building trust and enabling effective collaboration.

During early implementation, R&D team members hesitated to rely on model outputs without understanding prediction generation. As an AISmart project lead explained:

"In our initial meetings, the client told us: we need to see why the model is giving us this result - otherwise we won't trust it."

SweetCo and AISmart addressed this by humanizing the XAI system through enhanced user experience design and explainability features. Maia incorporated an "Explainer" module visualizing ingredient influences on predicted properties, and a dashboard for comparing different ingredient combinations. As one formulation specialist recalled:

"When the model showed us that one ingredient had a strong impact on viscosity, we could say: yes, that aligns with what we know - or, no, that doesn't make sense, and we can investigate further."

By investing in an intuitive interface balancing technical depth with accessibility, SweetCo enabled users to explore different explanation levels based on needs, establishing the XAI system as a dialogue partner rather than an inscrutable oracle

Tension 3: Speed vs. Accuracy in Innovation

The third tension involved balancing accelerated development through virtual experimentation with rigorous validation needs. While XAI adoption significantly reduced physical tests from approximately 150 to fewer than 30 trials and shortened time-to-market from seven to two months, product development still required careful attention to sensory attributes not fully assessable through simulation.

This tension manifested in decisions about transitioning from virtual to physical testing. As an R&D manager explained:

"We still need to test the prototypes in the lab and run sensorial evaluations. AI helps us focus, but it doesn't eliminate the need for validation."

SweetCo managed this through selective user involvement. Initially conducting broad dissemination for organizational acceptance, SweetCo progressively engaged users providing the most valuable feedback, effectively using the XAI system to identify and leverage key knowledge holders.

This strategy balanced speed and accuracy by focusing intensive evaluation on only the most promising formulations. As the Head of Innovation noted:

"What we expect is that the number of prototypes suggested by the algorithm drops drastically compared to the current process. Ours is a food company and we rely on a solid sensory evaluation of prototypes performed by humans."

By strategically determining which formulations to test physically, SweetCo accelerated the overall development process while maintaining necessary rigor in quality assurance.

Tension 4: Standardization vs. Customization

The final tension involved balancing standardized formulation approaches with adaptation to specific market, regulatory, and supply chain contexts. AI systems generally perform best with structured, consistent data, yet SweetCo's global operations required adaptation to diverse environments and constraints.

This tension became evident when considering XAI application across different product categories and geographic markets. As one project stakeholder noted:

"Some ingredients are blacklisted in certain countries, or unavailable at certain times. We can't rely on the same constraints for every project. We need to continuously configure constraints based on dynamic changes in regulations, market limitations, and customer preferences."

SweetCo addressed this through phased implementation beginning with a narrow, well-defined domain and gradually expanding to broader applications. As the AISmart project manager explained:

"Taking a sub-set of initial data is done for convenience and to arrive at a configuration of the solution more quickly, which can show the benefits to the client. Then we go on to expand this dataset so that Maia can support the entire formulation process, more products and more formulations, without going outside the focus of R&D."

Over time, SweetCo enhanced Maia customization capabilities by embedding additional constraints (ingredient availability, cost thresholds, regulatory requirements) into the

system. This allowed the XAI solution to generate recommendations both standardized in underlying logic and customized to specific contexts. Table I summarizes the paradoxical tensions, management strategies, and outcomes observed in the case.

TABLE I. SUMMARY OF PARADOXICAL TENSIONS AND MANAGEMENT STRATEGIES IN XAI IMPLEMENTATION

Paradoxical Tension	Description	Management Strategy	Key Outcome
Automation vs. Human Judgment	Tension between algorithmic efficiency and human creativity, intuition, and contextual understanding	Integration of XAI throughout innovation process with iterative feedback loops between human experts and AI	Positioning AI as collaborative partner rather than replacement for human expertise
Transparency vs. Complexity	Tension between sophisticated models capturing complex interactions and need for interpretability to build trust	Enhanced user experience design with explainability features visualizing key drivers behind predictions	Establishment of XAI system as dialogue partner with accessible explanation layers
Speed vs. Accuracy	Tension between accelerating development through virtual experimentation and ensuring quality through physical testing	Selective user involvement and strategic allocation of physical testing resources based on AI recommendations	Reduction in physical experiments from and time to market while maintaining rigorous quality assurance
Standardization vs. Customization	Tension between standardized approaches for model performance and adaptation to specific contexts and constraints	Phased implementation starting with narrow domain and progressively incorporating customization capabilities	Development of XAI solution generating contextually appropriate recommendations based on standardized principles

C. Strategies to Manage XAI Paradoxical Tensions

Across the four paradoxical tensions, two interrelated strategies emerged as central to SweetCo’s ability to manage competing demands: the design of feedback loops and the development of explainable interfaces. Feedback loops were critical in embedding XAI within the existing innovation workflow, allowing experts to continuously interact with algorithmic suggestions, validate outputs through experimentation, and refine both data and models based on experiential knowledge. This dynamic interaction not only mitigated concerns about automation replacing human expertise but also fostered mutual learning between human and XAI.

In parallel, interface design played a crucial role in addressing tensions around complexity, transparency, and control. By providing intuitive, visual explanations through the “Explainer” module and decision support dashboard, the system enabled R&D professionals to understand and trust Maia’s outputs without needing technical expertise.

These two strategies functioned as organizational mechanisms for managing paradoxes dynamically, rather than resolving them through one-sided solutions. They allowed SweetCo to sustain a productive equilibrium between innovation speed and quality, standardization and contextual adaptation, automation and expert intuition.

V. DISCUSSION AND CONCLUSION

This study investigated how organizations manage paradoxical tensions emerging during Explainable AI implementation in product development. Through a qualitative case study of SweetCo’s implementation of the XAI solution Maia, we examined how contradictions arising when integrating advanced technologies into established innovation routines are managed. Our findings contribute to theory and practice by extending the paradox perspective to AI-enabled innovation and providing actionable insights for organizations implementing XAI solutions.

A. Theoretical Contributions

First, our study extends the paradox perspective [10] to the emerging context of XAI integration in product innovation. While previous research identified paradoxical tensions in digital transformation broadly [7, 25], our findings reveal four specific tensions characterizing XAI implementation in

innovation processes: automation versus human judgment, transparency versus complexity, speed versus accuracy, and standardization versus customization. These tensions cannot be resolved through either/or choices but must be managed using both/and approaches accepting and working with contradictions. At SweetCo, this manifested through iterative feedback loops between human experts and the XAI system, enabling what Smith [11] describes as dynamic equilibrium accommodating seemingly incompatible demands.

Second, our findings challenge simplistic narratives of AI either replacing or augmenting human capabilities by demonstrating how XAI implementation catalyzes transformation of implicit knowledge into explicit knowledge. This extends von Krogh’s [27] work on AI in knowledge-intensive contexts by showing how implementation can make visible tacit patterns and relationships that experienced professionals understand intuitively. At SweetCo, training and refining XAI required R&D professionals to articulate implicit formulation knowledge, creating a virtuous cycle where human expertise informed algorithmic development and AI-generated insights prompted further human understanding refinement. This relationship transcends binary human versus artificial intelligence framing [26], showing co-evolution where both adapt and develop in response to each other.

Third, our study contributes to understanding how XAI systems reshape organizational processes by highlighting user experience design’s importance in facilitating effective human-machine collaboration. While technical XAI research focuses primarily on algorithmic approaches to explainability [5, 6], our findings demonstrate that implementation’s social and organizational contexts significantly influence how explanations are interpreted and utilized. SweetCo’s focus on creating an intuitive interface with layered explanations enabled users with varying technical expertise to meaningfully engage with system recommendations. This extends Orlikowski’s [24] technology-in-practice perspective by showing how XAI systems’ material features and users’ social practices co-evolve during implementation, ultimately shaping technology’s innovation process impact.

B. Practical Implications

From a practical perspective, our findings suggest that organizations gain the most value from XAI when they integrate it across the entire innovation workflow, rather than

isolating it to specific phases. This broad integration creates multiple opportunities for human-AI interaction and helps balance algorithmic efficiency with human expertise. At SweetCo, embedding the XAI solution throughout the development process positively impacted efficiency of physical experiments and time to market, accelerating innovation while preserving the accuracy of critical validations. This aligns with Thomke's [12] observation on the resource constraints of experimentation and demonstrates how virtual tools can extend, rather than replace, physical testing.

The study also underscores the importance of combining model sophistication with interpretability through user-centered interface design. At SweetCo, the "Explainer" module and decision support dashboard enabled R&D professionals to understand key drivers behind AI recommendations without needing technical knowledge of the algorithms. By making algorithmic logic transparent in ways that align with users' expertise, the system built trust and usability, addressing transparency concerns noted by Miller [21] and Castelvechi [20].

Finally, our results reveal that XAI implementation can act as a catalyst for articulating and formalizing tacit knowledge. At SweetCo, the process of training the XAI solution prompted experts to define implicit formulation patterns, converting personal and tacit know-how into organizational knowledge. This supports knowledge management goals [13] by providing structured opportunities to transform individual expertise into shareable, explicit knowledge.

C. Limitations and Directions for Future Research

While our study provides valuable insights into XAI integration in product innovation, it has limitations that suggest areas for future research. First, as a single case study in the confectionery industry, the generalizability of our findings to other contexts may be limited. Future studies could examine XAI deployment across multiple industries and organizational types to identify context-specific factors that influence how paradoxical tensions manifest and are managed. Second, our study focused primarily on the implementation phase rather than long-term outcomes. Longitudinal research could examine how human expertise and XAI systems co-evolve. In particular, it could track the interaction between knowledge formalization and algorithmic learning over time. Finally, our study did not extensively examine how different stakeholders, beyond R&D professionals, experience and interact with XAI systems. Future research could investigate how diverse organizational roles and professional identities shape perceptions of and engagement with XAI in innovation processes.

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