The Role of Serious Games for Boundary-Object Negotiation in Innovation Projects

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Abstract. Innovation projects that span multiple disciplines and organizations depend on cross-functional collaboration and knowledge integration to succeed. Boundary objects—shared artifacts, models, or methods that enable coordination across different social and knowledge domains—are key means for realizing such collaboration and integration. However, boundary objects are rarely self-explanatory or automatically accepted. To become effective, they must undergo negotiation cycles through the active participation of the actors involved in the collaboration. This negotiation process is difficult to achieve yet essential for developing shared understanding, fostering collective sensemaking, and enabling effective use of boundary objects. To facilitate this process, this paper explores Serious Games (SGs)—structured, goal-oriented games designed for purposes beyond entertainment—as potential mechanisms for boundary-object negotiation. SGs provide safe and analogy-based environments that may serve as catalysts for discussion and coordination among participants, enabling them to engage experientially within the iterative cycles of negotiation. This hypothesis was tested within a European rail innovation project, where a Business Case (BuCa) methodology acted as a boundary object for integrating domain-specific knowledge. An SG workshop, designed through a design-science research process and drawing on design-thinking principles enabled participants to understand, analyze, and refine the selected boundary object. The case study demonstrates how the SGs acted as a catalyst for cross-functional dialogue, facilitating the understanding and collective sensemaking of the boundary object. The findings highlight how playful, experiential interventions can enhance boundary-object negotiation and strengthen methodological alignment, especially in complex innovation environment.

Keywords: Innovation Management · Project Management · Asset Management · Cross-Functional Collaboration · Design Thinking.

1 Introduction

Innovation in today's technology-intensive environment increasingly depends on complex knowledge work, where experts from diverse domains must collaborate to combine and apply specialized expertise [7]. Such collaboration requires spanning multiple types of boundaries—disciplinary, organizational, cognitive, and social—to share information, coordinate tasks, and integrate heterogeneous knowledge [11]. Boundary spanning facilitates the division of work necessary to solve complex organizational problems; however, the diversity of boundaries can also inhibit experts from coordinating tasks, sharing knowledge, and brokering expertise [17]. Therefore, successful innovation projects demand effective *Cross-Boundary Spanning* mechanisms capable of linking multiple domains and fostering integration across disciplinary and organizational divides.

A key mechanism that supports cross-boundary spanning and knowledge integration in innovation projects is the use of *Boundary Objects* [30]. These establish a shared syntax or language for individuals to represent their knowledge across boundaries [11], enabling collaboration among actors who possess distinct expertise, goals, and vocabularies. Boundary objects can take multiple forms [10], such as prototypes, drawings, sketches, designs, simulation models, databases, or software platforms. Rather than requiring participants to fully transfer or assimilate one another's domain-specific knowledge, boundary objects act as knowledge catalysts, fostering cross-functional discussion and coordination around a shared representation of the problem at hand [26] [24].

Building on this perspective, negotiation can be broadly defined as "a discussion between parties in order to reach an agreement" [13]. In collaborative innovation settings where knowledge and expertise are dispersed, effective project coordination depends on the actors' ability to negotiate and reconcile their different understandings [27]. Within such contexts, boundary objects play a crucial mediating role by enabling individuals at the interface of different domains to represent, clarify, and translate knowledge across boundaries [12]. Empirical studies have shown that boundary objects act as key enablers of *Knowledge Negotiation*, particularly in complex design environments [15] [2].

While extensive research has examined how boundary objects facilitate the negotiation of knowledge across disciplinary and organizational domains, little attention has been paid to the negotiation of the boundary object itself. As highlighted by Bechky (2003) [8] and Tuertscher et al. (2014) [31], boundary objects do not automatically generate shared understanding; they must be continuously discussed, challenged, and refined by the actors involved in the collaboration. Despite these insights, to the best of the authors' knowledge, no study has systematically examined how the negotiation of boundary objects unfolds in practice or the mechanisms that can facilitate it. This need becomes particularly salient when the boundary object is not a well-established or standardized tool—such as a BIM model or a shared software repository—but a novel or project-specific artifact, as is often the case in innovation projects [10]. This highlights the need for empirical and methodological research on approaches that support *Boundary-Object Negotiation* in innovation settings.

In this context, Kilis et al. (2025) [20] emphasize that social interaction and active engagement are essential to generating the 'creative tension' required for boundary-object negotiation. *Serious Games* (SGs), understood as structured and goal-oriented activities designed for purposes beyond entertainment [1], offer participatory and experiential formats that inherently support such dynamic collaborative processes. However, while SGs have been used as boundary objects to support knowledge negotiation [19], they have not been examined as a means to facilitate the processes of boundary-object negotiation. This gap motivates the following research question (RQ):

How can Serious Games facilitate the process of Boundary-Object Negotiation in Innovation Projects?

To address this RQ, *The BuCa Restaurant* game was designed and implemented through a series of sessions within an innovation consortium. The experience was then analyzed to reflect on the role of SGs in supporting boundary-object negotiation. The remainder of the paper is structured as follows: Section 2 presents the theoretical background used to develop the SG. Section 3 details its design process. Section 4 outlines its application in multiple game sessions. Section 5 reports the results and addresses the RQ. Finally, Section 6 offers concluding reflections and directions for future research.

2 Theoretical Framework

In this section, the theoretical concepts underpinning the development of the SG are presented. Section 2.1 describes the utilized design methodology, Section 2.2 illustrates the experiential learning framework and Section 2.3 outlines relevant elements of Design Thinking.

2.1 Design Science

Design Science Research Methodology (DSRM) is a research approach aimed at creating and evaluating artifacts designed to solve identified problems [28]. It is particularly suitable for applied fields such as information systems, engineering, and management, where bridging theory and practice through the development of innovative tools or frameworks is essential. In this work, DSRM is adopted as the overarching *Methodological Approach* to guide the design of the SG.

DSRM comprises six steps, each of which is instantiated in this paper: (1) *Problem Identification* is addressed in the Introduction (Section 1), where the need for approaches that support boundary-object negotiation is established; (2) *Objective Definition* is detailed in Section 3.2, outlining the design requirements for the SG; (3) *Design and Development* is described in Section 3.3; (4) *Demonstration* is presented in Section 4, through the application of the SG in multiple game sessions; (5) *Evaluation* is provided in Section 5, assessing the SG's ability to support boundary-object negotiation; and (6) *Communication* of results is embedded throughout the paper, with conclusions summarized in Section 6.

2.2 Experiential Learning

Experiential learning is a pedagogical approach that emphasizes learning through direct experience, reflection, and active engagement. At its core lies *Kolb's Experiential Learning Cycle*, which comprises four stages [21]: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Learners first engage in a concrete activity, reflect on that experience, derive conceptual insights, and then test these insights through further action. This iterative process not only deepens understanding but also fosters adaptability, critical thinking, and meaningful knowledge transfer [29] [5]. In this study, the SG served as the concrete experience that prompted participants to reflect on the boundary object, generate conceptual insights about its structure and use, and iteratively refine it prior to its application in the project setting.

2.3 Design Thinking

Design Thinking (DT) is a human-centered, iterative, and creativity-oriented approach to problem solving that combines analytical reasoning with intuition and experimentation [9]. As Nagaraj et al. (2020) [25] argue, DT principles—such as user empathy, collaborative abduction, rapid iteration, and multimodal representation—help teams overcome the routine-based and cognitive inertia that typically constrain their innovativeness by encouraging the creation, experimentation, and negotiation of shared artifacts that function as boundary objects. Building on these principles, we developed an SG as a tangible artifact intended to serve as a means for facilitating boundary-object negotiation.

Beyond its underlying principles, DT also offers a set of practical tools [23]. In particular, *analogy* was employed to situate participants in a simplified and risk-free scenario—distinct from their actual work context—thereby enabling them to engage with the boundary object without organizational pressures or domain-specific constraints. Furthermore, *visualization* techniques supported the externalization of ideas, enabling participants to collectively envision the boundary object and negotiate its structure and meaning.

3 Design Process

This section begins by outlining the context in which the approach was developed (Section 3.1), then presents the design process of *The BuCa Restaurant* game, starting with the definition of its core objectives (Section 3.2), followed by a description of the methodological steps used in its development (Section 3.3).

3.1 Project Context

The Europe's Rail Joint Undertaking (ERJU) is the EU's main instrument for coordinating research and innovation in the rail sector, aiming to deliver a high-capacity, integrated, and digital European rail network. Within this framework, Flagship Project 2 (FP2)—titled *Rail to Digital Automated up to Autonomous Train Operation* (R2DATO) (https://rail-research.europa.eu/pages/fp2-r2dato/deliverables)—focuses on advancing automation and digitalisation in both passenger and freight transport. FP2-R2DATO seeks to develop and deploy scalable

Digital and Automated (up to Autonomous) Train Operation (DATO) technological solutions, contributing to the modernization and capacity enhancement of the existing rail infrastructure.

Within FP2-R2DATO, Work Package 32 (WP 32)—*DATO Assessment and Potential Identification*—plays a central role in bridging technical innovation with strategic deployment. This work package is tasked with integrating insights from diverse research streams into a cohesive and generalizable Business Case (BuCa) methodology aimed at assessing DATO technologies [4]. WP 32 brings together a diverse consortium, including national autorities (DLR, NRD and Trafikverket), train operators (NS and RENFE), freight operators (DB Cargo), infrastructure managers (ProRail and ADIF), and academic partners (NTNU, LTU, KTH, TU Delft, and the University of Twente).

In this context, the *Value-based Multi-Criteria Decision Analysis* method presented in [6] was selected as a blueprint for the BuCa methodology due to its ability to function as a boundary object by integrating multiple knowledge dimensions. However, rather than being used to compare alternative options (e.g. DATO technologies), the methodology was adapted to compare the impacts on different stakeholders within a specific application scenario—that is, a given DATO technology and set of network characteristics. This adaptation necessitated a negotiation process within the consortium to establish shared understanding, collective sensemaking, and effective use of the boundary object.

3.2 SG Objectives

The development of the SG was guided by three primary objectives, aimed at ensuring its relevance, applicability, and effectiveness in supporting boundary-object negotiation. These objectives are:

- *Obj1) Boundary Object*: the core steps of the selected boundary object had to be implemented within the SG to allow participants to enact and explore the BuCa methodology in practice;
- *Obj2) Analogy*: the SG had to implement an analogy-based scenario that mirrors the structural logic of the methodology while remaining sufficiently detached from the real project context, thereby providing a simplified, safe, and cognitively accessible environment in which participants could understand, experiment with, and reflect on the approach;
- *Obj3) Negotiation*: in line with [22], the SG needed to enable boundary-object negotiation through iterative processes of: (i) *Articulation*—expressing and externalizing domain-specific knowledge through the boundary object; (ii) *Alignment*—connecting and adjusting these articulations with those of others; (iii) *Contestation*—identifying and debating conflicts or differences in how the boundary object is interpreted, represented, or operationalized; and (iv) *Transformation*—adapting the boundary object to incorporate collective insights.

3.3 SG Design

This section presents the design of the SG, following the objectives identified in Section 3.2.

In accordance with *Obj1*, the SG had to implement the steps of the methodology presented in [6], adapted to compare the impacts on different stakeholders within a specific application scenario. These steps are as follows:

1. *Application Scenario*: consists in specifying the considered DATO technologies and the network characteristics in which they will be applied, as well as identifying the relevant stakeholders involved in or affected by their implementation;
2. *Value Drivers and Metrics*: in Asset Management (AM), value represents the result of considering both positive and negative impacts, as well as financial and non-financial effects, on stakeholders [18]. In this context, value can be expressed as performance less cost in relation to the associated risks [16]. Within each of these three dimensions, value drivers (or enablers) are factors that significantly influence the realization of value, while value metrics (indicators) are the performance measures used to assess these drivers [14]. In this step, a hierarchical tree of value drivers and their corresponding metrics is built for each value dimension;
3. *Utility functions*: a utility function is associated to each metric enabling the representation of the impacts on different stakeholders within a specific application scenario;
4. *Weights*: weights are assigned enabling the expression of the relative importance of drivers and metrics in the aggregation of overall value;
5. *Value Model*: the overall additive utility functions are computed using the individual utility functions formulated in step 3 and the weights assessed in step 4.
6. *Validation*: a sensemaking exercise is conducted to discuss, interpret, and critically reflect on the results of the value model.

In accordance with *Obj2*, the SG had to be based on an analogy that mirrors the structural logic of the BuCa methodology while remaining sufficiently detached from the real project context. A culinary analogy was selected for this purpose, as it had already been employed within the consortium to build a shared vision [4], and participants were therefore familiar with it.

The narrative of *The BuCa Restaurant* game was designed to mirror the consortium task of developing a BuCa methodology to support the adoption and implementation of DATO technologies. In the game scenario, BuCa is portrayed as a well-established and rapidly growing chain of restaurants whose expanding customer base has begun to strain its operational capacity. Despite its commercial success, the company faces increasing labor shortages and operational inefficiencies, limiting its ability to meet rising demand. To address these challenges, BuCa seeks to explore digitalization and automation as strategic enablers of improved performance and resilience. In this context, a governmental "Angel Program" is available to support businesses like BuCa willing to experiment with innovative digital solutions. To access this funding, applicants must submit a compelling illustration of the business case for the proposed digitalization technologies, thereby framing the core challenge of the game.

The project consortium comprised three domain-specific teams—capacity, human factors, and cost—which can be aligned, respectively, with the three AM value dimensions of performance, risk, and cost considered in AM. To preserve this domain-specific structure and maintain manageable group sizes, three separate game sessions were designed. Furthermore, given that the full application of the BuCa methodology would have required more time than was available within a single game session, only the impact assessment was implemented during the domain-specific sessions. The remaining misalignment assessment and reflective components—namely, the *Obj3* negotiation process—were conducted in a subsequent plenary session involving all three teams. This division is illustrated in Table 1.

Table 1. Mapping of the BuCa methodology steps across the game (domain-specific) sessions and the subsequent reflection (plenary) session.

BuCa Methodology	**Game Sessions**	**Game Reflection**
Application Scenario	Meet BuCa	/
Value Drivers and Metrics	Hierarchical Trees	Value Framework
Utility Functions	Semaphore-based Assessments	Metric-level Misalignments
Weights	/	Weighted Metrics
Value Model	Impact Visualizations	Driver-level Misalignments
Validation	/	Boundary-Object Negotiation

4 The BuCa Restaurant Game

The game sessions of *The BuCa Restaurant* are presented in Section 4.1, while Section 4.2 describes the subsequent reflection session.

4.1 Game Sessions

Each session consisted of four phases designed to enable participants to: (i) understand the BuCa methodology and how their team could contribute to assessing the impacts of a given technology on different stakeholders; and (ii) propose visualizations to highlight these impacts. These phases are described below (Table 1):

1. *Meet BuCa*: the application scenario described in Section 3.3 was introduced, including the restaurant's demand-related challenges, the potential culinary digital technologies, and the stakeholders involved in or affected by the decision problem;
2. *Hierarchical Trees*: prior to the game sessions, the main metrics previously identified by the domain-specific teams were clustered into value drivers to construct hierarchical trees—one for each team. These railway-based metrics were then translated into the culinary context, as illustrated in Figure 1. During the game session, the resulting hierarchical trees were presented to the participants as the basis for the subsequent assessment activities;

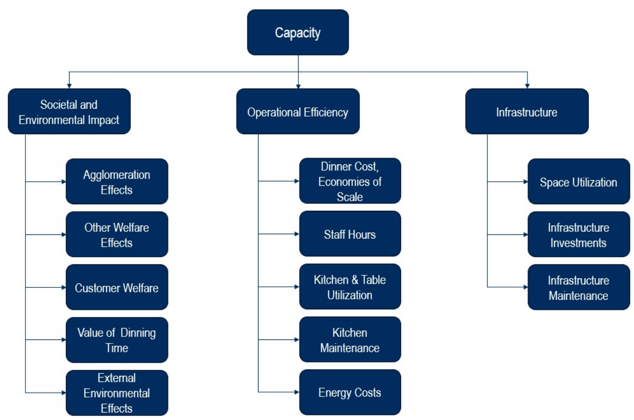

Fig. 1. Hierarchical tree for the Capacity value dimension used in *The BuCa Restaurant* game, including three value drivers and thirteen metrics.

3. *Semaphore-based Assessments*: in this phase, participants were asked to assess the impacts on different stakeholders with respect to each metric. To facilitate this, a semaphore-based assessment (green, yellow, red) was adopted, enabling players to grasp the underlying logic of the evaluation process, which in the real project context would be implemented through formal utility functions. Each team focused on assessing stakeholder impacts within its respective value dimension: the capacity team examined performance-related (gain) impacts, the cost team focused on cost-related impacts, and the human factors team addressed impacts related to the allocation of responsibility for mitigating technology adoption risks (see Figure 2);
4. *Impact Visualizations*: in the final phase, participants were asked to propose visualizations to highlight the impacts on different stakeholders, considering that four key variables could be represented: stakeholders, technology, value drivers/metrics, and assessment results. This activity served two purposes.

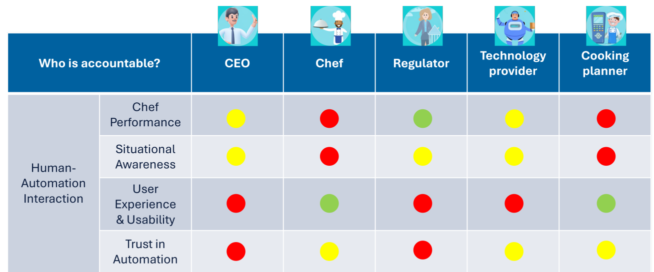

Fig. 2. Excerpt of the semaphore-based assessment for the human factors team. Value drivers are listed in the first column and their corresponding metrics in the second, while the colored indicators represent stakeholder accountability levels (red = high, yellow = medium, green = low).

First, it supported the acceptance of the proposed BuCa methodology by allowing participants to shape how their outcomes would be communicated. Second, visualizing the expected outputs of the assessment helped clarify what each team would need to produce in the real project context.

The game sessions took place in Utrecht (The Netherlands) on 17 February 2025 (cost team), 25 February 2025 (human factors team), and 13 March 2025 (capacity team), respectively. Each session lasted approximately 2.5 hours and was conducted in a hybrid format, enabling participants located abroad to take part in the game. *Miro* (https://miro.com/) was used as the primary platform, allowing players to perform the assessment and develop the impact visualizations.

After the game sessions, the visualizations produced by each team were reviewed, and the one depicted in Figure 3 was selected to represent stakeholder impacts within each value dimension. This visualization contains a *Value Curve* for each stakeholder and was chosen because it effectively integrates the four key variables—stakeholders, technology, value drivers/metrics, and assessment results—into a single representation.

4.2 Game Reflection

The reflection session took place in Utrecht on 24 March 2025. It included members of the three teams—capacity, cost, and human factors—and had the following purposes: (i) *Integrated results*: illustrate how the different domain-specific impact assessments could be integrated to highlight potential stakeholder misalignments; and (ii) *Boundary-object negotiation*: negotiate the proposed BuCa methodology based on the provided overview. To support these purposes, the following elements were presented to the participants, as indicated in Table 1:

1. *Value Framework*: in AM, a Value Framework (VF) defines the value elements of an organization [14]; that is, the elements that deserve proper attention and control because they influence value realization. According to

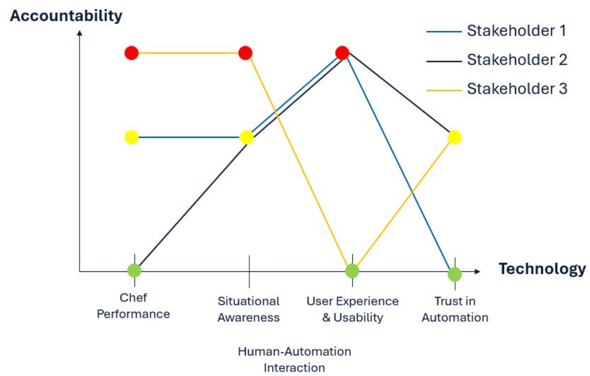

Fig. 3. Example of the selected visualization used to represent the impacts of a given technology on different stakeholders across the metrics of the Human–Automation Interaction value driver.

[3], a VF comprises distinct value dimensions, each encompassing multiple value elements represented as tuples of value drivers and value metrics. Because the hierarchical trees resemble the structure of a VF, this tool was selected to integrate the three value dimensions (Figure 4);

2. *Metric-level Misalignments*: by assessing the impacts on different stakeholders with respect to each metric through utility functions and integrating the resulting value curves, the representation shown on Figure 5 is obtained. This representation enables the identification of stakeholder misalignments at the metric level. In this context, misalignment refers to potential trade-offs among stakeholders with respect to benefits, costs, and risks. For example, a stakeholder who obtains limited gains, faces high costs, and bears high responsibility for mitigating risks would likely oppose the introduction of the considered technology;
3. *Weighted Metrics*: as can be observed from Figure 5, the large number of metrics makes the identification of stakeholder misalignments difficult. To synthesize the results and support decision-making, weights can be assigned to the different metrics according to their relative importance within each value driver;
4. *Driver-level Misalignments*: a weighted sum is applied to the utility functions of the metrics associated with each value driver; see [6] for details. This aggregation enables the assessment of stakeholder impacts at the driver level, producing a more compact representation of potential stakeholder misalignments (Figure 6).

Following the presentation of these elements, participants engaged in a discussion aimed at negotiating the proposed BuCa methodology.

Fig. 4. Value framework for the DATO BuCa project. The figure illustrates three value dimensions and nine value drivers. Metrics are associated with each driver to complete the framework as illustrated in Figure 1 for the capacity dimension.

5 Results and Discussions

Section 5.1 presents the results of applying the SG within the project context, while Section 5.2 discusses how SGs can facilitate boundary-object negotiation.

5.1 BuCa Methodology: Boundary-Object Negotiation

Feedback from the teams indicated that the SG contributed to a clearer *understanding* of the BuCa methodology through hands-on application. For instance, the Human Factors team noted that "the SG helped define the relationship between the domain-specific metrics, the BuCa, and the stakeholder perspectives," while the Cost team highlighted that "the SG helped clarify the level of detail required for the assessment of the metrics." This improved understanding provided the basis for cross-functional dialogue during the reflective session, which led to a deeper *analysis* and *refinement* of the selected boundary object.

As a result of this discussion, the following decisions were made:

- *BuCa methodology*: the proposed methodology was accepted as the boundary object, including the use of constructed attributes for stakeholder impact assessment and visualizations to highlight potential misalignments;
- *Visualizations*: a linear representation (rather than a circular one) was selected for both the VF and the misalignment plots. This choice reflects the fact that a circular representation could suggest a comprehensive visualization of all benefit, cost, and risk elements, while the present study focuses only on the capacity, cost, and human factors dimensions;
- *Time dimension*: the temporal dimension (e.g., technology roadmap and dependencies) was excluded and left as future work.

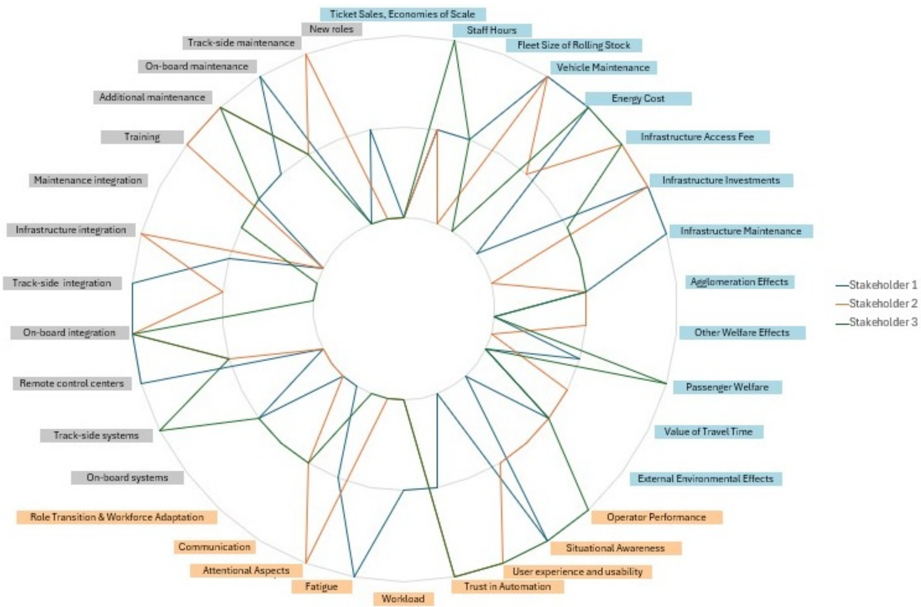

Fig. 5. Metric-level misalignment visualization. The figure integrates metrics from the capacity, cost, and human factors value dimensions, while the value curves represent stakeholder impacts across these metrics, enabling the identification of potential trade-offs.

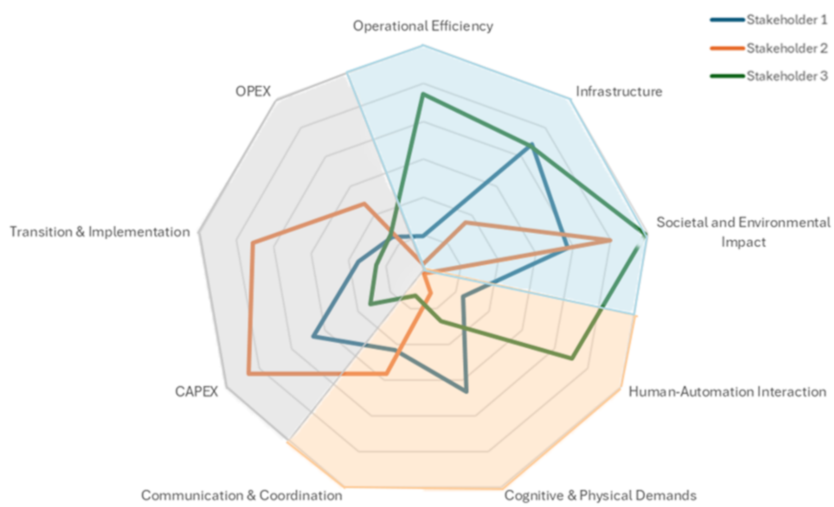

Fig. 6. Driver-level misalignment visualization. Driver labels are indicative and should not be interpreted in detail, as the focus of this paper is on illustrating the methodological approach.

Finally, although the use of analogy generated mixed reactions—some participants initially felt unfamiliar with the culinary domain—the strength of the approach lies in enabling teams to *anticipate* and *negotiate* the integration of domain-specific outcomes before they fully materialize, within a simplified and safe environment. In doing so, the SG: (i) helps overcome potential cognitive inertia through its hands-on approach; and (ii) reflects the principles of iterative innovation practices, such as Agile frameworks like Scrum, where shared understanding develops through cycles of experimentation, feedback, and refinement.

5.2 Serious Games for Boundary-Object Negotiation

In line with [22], negotiation refers to iterative processes of articulation, alignment, contestation, and transformation. To address the RQ, we now illustrate how SGs can facilitate each of these processes, building on the results obtained in the project context:

- *Articulation*: SGs facilitate articulation by creating controlled, analogy-based settings in which participants must externalize their knowledge through the boundary object, making previously tacit assumptions visible to others;
- *Alignment*: SGs facilitate alignment by creating situations in which the domain-specific knowledge of different teams must be integrated through the boundary object toward a shared goal;
- *Contestation*: SGs facilitate contestation by creating experiential situations in which participants reflect on the game outcomes and debate differences in how the boundary object is interpreted, represented, or operationalized;
- *Transformation*: SGs facilitate transformation by enabling participants to modify the boundary object based on the collective insights generated through the game experience and subsequent reflection.

In conclusion, the project experience demonstrated that, especially in complex innovation consortia—where participants and knowledge are distributed across disciplinary and organizational boundaries and the boundary object is not a standardized tool—such experiential practices act as catalysts for cross-functional dialogue, supporting the development of shared understanding, fostering collective sensemaking, and enabling the effective use of boundary objects.

6 Conclusion and Future Work

This paper examined how SGs can facilitate boundary-object negotiation in innovation projects. Using a design-science research approach and design-thinking principles, an SG was developed and applied within a European rail innovation project to support the negotiation of a Business Case (BuCa) methodology that acted as a boundary object. The findings indicate that the game facilitated participants' understanding of the methodology through hands-on experimentation and acted as a catalyst for cross-functional dialogue. In particular, it enabled processes of articulation, alignment, contestation, and transformation, thereby supporting collective sensemaking and refinement of the methodology. These results suggest that experiential and analogy-based interventions can facilitate boundary-object negotiation in complex innovation consortia. Future research should investigate the transferability of this approach to other collaborative innovation settings and evaluate its long-term impact within the current project context.

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