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Enabling systemic innovation: hybrid risk management and knowledge translation in the NEMESI project

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Abstract

Purpose – This paper aims to explore the role of hybrid risk management (HRM) as a strategic enabler of knowledge translation (KT) in high-risk, innovation-driven projects. It investigates how HRM can bridge gaps across disciplines, functions and organizations to facilitate actionable innovation.

Design/methodology/approach – This study relies upon a framework that draws from the KT model developed by Dal Mas *et al.* (2023), positioning HRM as a critical KT tool in innovative project management. This framework is used to drive the data collection and analysis of a qualitative case study based on interviews and analysis of archival data, examining the NEMESI project – an industrial-scale initiative led by Leonardo S.P.A. to digitize aerostructure production.

Findings – The findings demonstrate that HRM supports a culture of learning, adaptive risk response and collaborative knowledge exchange. HRM was shown to be a dual tool: reducing risk while creating value through embedded knowledge practices.

Originality/value – This research advances the integration of risk management and KT in project governance. It offers a novel, actionable framework for enabling systemic innovation, addressing a key gap between project management theory and practice in complex innovation settings.

Keywords Hybrid risk management (HRM), Knowledge translation (KT), Innovation projects, Organizational learning, Digital transformation

Paper type Research paper

1. Introduction

Amid rapid technological change and market volatility, organizations must adopt innovative project management approaches to remain competitive. Traditional risk management frameworks often fall short in dynamic, knowledge-intensive environments due to their rigid processes and limited responsiveness (Raz and Michael, 2001; Perminova *et al.*, 2008). Hybrid risk management (HRM), which synthesizes traditional predictive and agile adaptive methodologies, has garnered increasing attention as a flexible approach suited to complex project landscapes (Conforto *et al.*, 2016). While operationally effective, HRM's role in enabling knowledge translation (KT) remains underexplored (Mitchell *et al.*, 2021). Through feedback loops and stakeholder engagement, HRM can translate tacit and explicit knowledge

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into actionable insights, thereby enhancing decision-making, proactive risk mitigation and project success (Turner and Müller, 2005; Geraldi *et al.*, 2011).

This study investigates how HRM and KT intersect within innovative projects, adding to current discourse on adaptive risk practices and organizational learning, in line with systems innovation theory, which views innovation as driven by sociotechnical transitions and dynamic interactions (Geels, 2004; Meadows, 2008). This study seeks to address the following central research question:

RQ1. How does hybrid risk management enable knowledge translation in complex innovation projects toward value creation for different stakeholders?

This question is crucial to understanding how organizations can transform fragmented knowledge into innovation under conditions of uncertainty. It offers insights that extend beyond the specific context and enhance our understanding of how social, technical and institutional systems shape innovation outcomes (Geels, 2004; Meadows, 2008).

Theoretically the paper builds upon the insights from Dal Mas *et al.* (2023), positioning HRM as a critical KT tool in innovative project management, which face unique risks due to their high levels of uncertainty and evolving requirements (Cooper, 2019). Such an integration offers a balanced approach by embedding iterative risk reviews, stakeholder engagement and adaptive strategies into the project lifecycle (Schieg, 2006). This ensures that risks are not only identified and mitigated but also leveraged as opportunities for learning and innovation.

This framework is used to examine the case of the NEMESI project. Under the NEMESI project, which stands for New Engineering and Manufacturing Enhanced System Innovation, Leonardo S.p.A.'s Pomigliano d'Arco and Nola sites, producing aerostructures in the province of Naples, are becoming smart factories using new-generation industrial processes based on digitalization, automation and application of disruptive technologies inspired by the paradigm of Industry 4.0.

The paper shows that NEMESI stands out as a successful model of knowledge-intensive collaboration within a complex industrial ecosystem and describes how systemic innovation has been fulfilled thanks to the integration of varied epistemic cultures, effectively transforming fragmented knowledge into cohesive, actionable insight. Paramount, on this regard, the role of HRM as an enabler of successful KT toward tangible and intangible innovation outcomes. By aligning academic insights with industrial expertise NEMESI enabled cross-functional learning and sustained innovation managing uncertainty and fostering knowledge transfer toward a resilient innovation ecosystem. The NEMESI analysis is central to understanding how organizations manage uncertainty and enable innovation by translating knowledge across functional and epistemic boundaries. It provides a fertile ground to address this question in a real-world, multi-actor, innovation ecosystem well beyond the one under specific scrutiny.

The reminder of this paper is structured as follows. Section 2 presents the background referring to extant literature on the topics under scrutiny. Section 3 describes the integrated theoretical framing. Section 4 describes the research design. Section 5 taps into the study's findings. Section 6 offers a discussion of the results, while Section 7 is devoted to the concluding remarks.

2. Background

Risk management processes are fundamental for any organizations, particularly those engaged in complex, high-risk innovative projects (Muntés-Mulero *et al.*, 2019). Indeed, risk management techniques allow companies to improve project diagnosis and achieve the best trade-off between the success and failure of projects (Bowers and Khorakian, 2014). By systematically assessing risks, managers can define a more realistic expectation for their

innovation strategies and develop adequate contingency plans (da Silva Etges and Cortimiglia, 2019). Risk management has long played a crucial role in innovative project management, traditionally relying on structured approaches (Hillson and Simon, 2020). However, increasing complexity and uncertainty in contemporary projects necessitate a more adaptive and flexible management approach. Innovative models of risk management, rooted in iterative processes and continuous stakeholder engagement, may offer an alternative, although they can lack robustness for large-scale initiatives (Conforto *et al.*, 2014). Beyond the classical schedules of risk analysis, the use of HRM seeks to combine the predictability of traditional risk management with the adaptability of agile methods and tools, enabling a more responsive and resilient approach to uncertainty (Raz and Michael, 2001). Unlike traditional methods, the HRM model integrates the advantages of hierarchical holographic modeling (HHM), enterprise-wise risk management (ERM), and risk filtering, ranking, and management, thereby bridging the gap between industrial and enterprise-level risk management (Lai and Lau, 2012). Indeed, many of the traditional risk management methodologies focus on a static assessment of risks, making them inadequate for addressing the continuously evolving project risk profile as a key critical challenge in today's pivot-oriented world (Muntés-Mulero *et al.*, 2019). Less formalized and hybrid approaches reconcile tensions between exploration and control, enabling adaptive responses to uncertainty (Martyn *et al.*, 2016; Chapman, 1997). Such systems not only identify and assess risk but also embed *cognitive frames* that guide how risks are interpreted and communicated across actors (Mikes, 2009).

Agile risk management tools can enhance transparency and stakeholder collaboration (Muntés-Mulero *et al.*, 2019), facilitating KT in innovative projects. KT involves transferring, synthesizing and applying knowledge to improve decisions and practices (Graham *et al.*, 2006). Scholars argue that barriers to knowledge transfer hinder value creation and the achievement of competitive advantage (Fang *et al.*, 2013). Hence, in project management, KT is essential for ensuring that insights from risk assessments are effectively managed, communicated and operationalized. In this regard, Temple and Landaeta (2020) support the idea of a strict relationship between inter-project knowledge transfer and managing countervailing risks. While explicit knowledge, such as documented risk registers, can be easily transferred, tacit knowledge – insights gained through experience – often presents a challenge (Nonaka *et al.*, 1996). Scholars argue that tacit knowledge is important for value creation, but the risk of its transfer between organizational members is high (Massingham, 2010). Since HRM provides a holistic and flexible approach that facilitates integration of diverse sources, promotes cross-functional collaboration and fosters a learning-oriented culture, it can meaningfully enhance KT and deliver value to stakeholders. This is also paramount to understanding how firms manage risk and uncertainty when engaging in innovation projects (O'Connor *et al.*, 2008) that are usually shaped by socio-technical transitions and dynamic system interactions (Geels, 2004; Meadows, 2008).

3. Theoretical framework: knowledge translation toward innovation under hybrid risk management

Innovation processes often hinge not solely on the generation of knowledge, but on the *translation* of that knowledge into actionable, context-sensitive practices. The concept of KT, rooted in the transformation of knowledge across contextual, cultural and disciplinary boundaries, has gained traction in management and strategy research as a critical enabler of organizational learning and innovation (Savory, 2006; Lemire *et al.*, 2013).

KT diverges from traditional notions of knowledge transfer by emphasizing the recontextualization of knowledge to fit diverse stakeholder understandings and practical

exigencies (Carlile, 2004; Milagres and Burcharth, 2019). It encompasses the reinterpretation, adaptation and integration of both tacit and explicit knowledge across functional silos, hierarchies and stakeholder groups. This function becomes particularly salient in high-stakes environments, such as those characterized by innovation under conditions of uncertainty and risk, where the coordination of dispersed expertise is essential for value creation.

In such domains KT and hybrid governance must accommodate emergent, nonlinear processes with distributed agency (Holland, 1992; Snowden and Boone, 2007), principles of complexity-informed governance become paramount. This approach favors evolving, collaboratively shaped solutions over centralized control, mobilizing distributed leadership and self-organizing structures enabling adaptability and flexibility (Heylighen, 2001; Uhl-Bien and Arena, 2018).

Indeed, in innovation settings, KT is inherently a multilevel process, spanning individual cognition, team-based interaction and organizational routines. Research from Dal Mas *et al.* (2023) provides empirical support for KT as a bridging mechanism in start-up ecosystems, where actors with divergent knowledge bases – entrepreneurs, consultants, public entities – translate strategic, financial and operational knowledge through tools like business plans. This aligns with findings from strategy literature emphasizing the criticality of dynamic capabilities and organizational learning (Teece, 2007; Eisenhardt and Martin, 2000).

KT can be positioned within the knowledge-based view (KBV) of the firm, which posits that competitive advantage derives from the firm's ability to integrate and apply dispersed knowledge (Grant, 1996). In innovation contexts, this requires translation mechanisms that allow novel, often ambiguous knowledge to be rendered actionable (Nonaka and von Krogh, 2009). Translation, thus, facilitates *absorptive capacity* – the ability to recognize, assimilate and apply external knowledge (Cohen and Levinthal, 1990) – which is essential for innovation. The integration of HRM into innovation processes – combining formal systems (e.g. KPIs, control systems) with informal, interpretive practices (e.g. narratives, relational governance) – provides a fertile ground for KT to occur. Hybrid approaches enable adaptive responses to uncertainty (Martyn *et al.*, 2016; Chapman, 1997) and embed *cognitive frames* that guide how risks are interpreted and communicated across actors (Mikes, 2009). These interpretive mechanisms – embedded in practices like scenario planning or cross-functional workshops – act as KT platforms, making complex strategic knowledge intelligible across domains. Dal Mas *et al.* (2023) illustrate this via business plans that translate technical, marketing and financial knowledge into investor-facing narratives.

This view is corroborated by several studies. For instance, Miller *et al.* (2008) argue that organizations using interdisciplinary routines for innovation mitigate uncertainty by synthesizing insights from multiple knowledge domains – effectively performing KT. Similarly, Knight and Trowler (2001) highlight that effective innovation under uncertainty requires *context-sensitive knowledge application*, not merely transfer. The success of KT in innovation hinges on participatory dynamics. Dal Mas *et al.* (2023) emphasize stakeholder participation – entrepreneurs, public agencies, consultants – as a core component of KT in entrepreneurial ecosystems. This resonates with the relational view (Dyer and Singh, 1998), which underscores the importance of inter-organizational routines and social capital for knowledge exchange.

KT works best when users co-create meaning and adapt knowledge to their specific contexts (Weick *et al.*, 2005). HRM plays a facilitating role by creating safe environments for experimentation, reducing the fear of failure and enabling feedback loops – all crucial for iterative KT. The efficacy of KT directly impacts innovation performance. Business plans, for instance, function not only as static documents but as KT artifacts – living documents that

evolve as entrepreneurs engage with various stakeholders. These artifacts help align visions, translate technical potential into commercial viability, and communicate risk and opportunity to investors (Karlsson and Honig, 2009; Shane and Delmar, 2004). Effective KT ensures that innovations are not only conceived but executed with alignment between technical, strategic and operational dimensions. HRM enhances this alignment by balancing rigor and flexibility – traits necessary to translate knowledge into actionable strategies under uncertainty (Martyn *et al.*, 2016).

It is worth remarking that from an operational perspective, the framework outlined above is centered on the understanding that KT is not the *transformation* of that knowledge to fit the needs, languages and practices of diverse actors (Carlile, 2004; Dal Mas *et al.*, 2023), which is pivotal in uncertain environments, where innovations must be both viable and legible to diverse stakeholders (Teece, 2007). Along with it, HRM systems – blending control and flexibility – create a context where KT thrives, allowing innovation to emerge (Martyn *et al.*, 2016; Mikes, 2009). Notably, translating these abstract concepts into empirical observation requires clarity on *how* to analyze a case.

The framework below (Table 1) outlines five interdependent dimensions that should guide data collection and analysis in case studies focused on KT and innovation under hybrid risk regimes.

The above table shows the dynamic interconnection between dimensions, on the ground that:

- Knowledge begins as tacit or siloed.
- Through translation mechanisms, it becomes more accessible.
- Actors interact, shaping understanding and application.
- This interplay is moderated by hybrid risk systems.
- KT culminates in tangible innovation outcomes.

Each layer and these interconnections are relied upon in the current paper to design interview protocols and coding and to understand how the NEMESI project navigates innovation risk. This framework contributes theoretically by integrating KT with hybrid risk governance in

Table 1. Operational framework

Dimension	Description	Indicators
Knowledge characteristics	What is the nature of the knowledge being translated?	Tacit vs. explicit, internal vs. external, stakeholder interpretation gaps
Translation mechanisms	What tools or interactions facilitate KT?	Business plans, workshops, storytelling, accounting tools, design artifacts
Actors and stakeholders	Who is involved in the KT process, and how do roles, power and agency differ?	Role clarity, stakeholder mapping, co-creation efforts, knowledge brokers and validators
Hybrid risk management	How is risk managed using both formal and informal systems, and how does this affect KT?	Scenario planning, dashboards + dialogue, budgeting tools, feedback loops
Translation outcomes	What tangible innovation results emerge from KT activities?	Strategic alignment, feasibility, innovation pivots, investment attraction, project performance

Source(s): Authors' own work

innovation contexts, and operationally by equipping researchers and practitioners with a structured lens to observe, code, and evaluate KT processes.

4. Research design

As already stated, the NEMESI project represents the center of our analysis. The NEMESI project (the acronym stays for *New Engineering and Manufacturing Enhanced System Innovation*) is a Research, Development and Innovation (R&D&I) initiative promoted by Leonardo S.p.A. as main Proponent [1]. The strategic objective of the project is the integrated digitization of production processes in the field of complex aerostructures, with reference to a section of the fuselage of the ATR 72.

The project aims to design and implement a full-scale technology demonstrator, digitizing the product lifecycle from development to maintenance, the integration of enabling technologies (KETs), the development of innovative training modules for operators and technicians, and the introduction of predictive monitoring systems and intelligent maintenance.

The partnership of the NEMESI project consists of 14 entities: Leonardo S.p.A. as the Proponent Subject and 13 Adhering Subjects. This consortium was selected to ensure a complementary set of skills, with representation from large industry, SMEs, universities and experts in enabling technologies, training, quality control, information systems and robotics. Among the partners, a paramount role is played by the University of Naples Federico II as the main scientific partner and contributor to multiple areas. Moreover, for the purpose of the study at hand, the perspective of these institution is paramount as it played a primary role in the issues of governance and risk management.

It is worth noting that NEMESI is not limited to sectoral interventions but intervenes systemically across the entire production chain. The pilot case is the ATR fuselage, but the solutions developed and implemented are scalable to other aircraft models and sectors as well. The project is closely related to the upgrading of Leonardo's plants in Pomigliano d'Arco and Nola, where design, assembly and metal structure machining operations are carried out. It has been realized around 9 Work Packages and its innovativeness is related to the breadth and ambition of activities, the full-scale integration of enabling technologies, the interdisciplinary approach, involving not only engineering, but also education, law, economics, occupational medicine and the ecosystemic, land-oriented and extended-industry vision.

The data based on archival sources and semi-structured interviews were collected over the period April 2024–April 2025. The interviews followed an agenda of topics rather than a structured set of questions, to gain a detailed picture of the practices and issues involved in the HRM practices developed and in the KT virtuous processes possibly activated.

Following Ahrens and Chapman (2006), the interviews aimed to build up a deeper picture following the theoretical constructs presented in Section 3. That is, tapping into the nature of knowledge being translated, the tools or interactions facilitating such KT, the actors involved, their roles and any power relations significant, the use of formal/informal risk management systems and effects in terms of KT, the tangible results emerging from KT in terms of innovation.

Two researchers conducted each hour-long interview to reduce pressure on participants to provide 'correct' answers. When necessary, researchers asked for examples and/or confirmation, using re-phrasing strategies. Interviews with six individuals, some repeated, were held online. These were digitally recorded and transcribed for analysis. A telephone follow-up was conducted when data were missing. The interviewees were asked to review the transcripts and to make any corrections. The transcripts were manually analyzed through

a structured, two-step coding process. Initially, open coding was applied to identify emergent themes directly from the raw data, focusing on participants' language, perceptions and experiences. These themes were then iteratively grouped into broader categories aligned with the five analytical dimensions of the proposed framework. The coding was carried out independently by two researchers, who then compared results through regular discussion sessions to ensure consistency and reduce subjective bias. Divergences in interpretation were reconciled through joint reflection, enabling a robust and transparent analytical process. This approach allowed us to systematically trace patterns across different stakeholder groups and to reinforce the internal validity of the findings.

5. Findings: governance, risk management and collaboration in the NEMESI project

5.1 Nature of knowledge

The knowledge activated, developed and transformed throughout the NEMESI project is of an inherently complex nature – heterogeneous, layered, contextual and deeply transdisciplinary. From the earliest phases of analysis and design, it became evident that the project would need to navigate and integrate multiple forms of knowledge, each characterized by its own epistemology and expressive mode.

A key distinction within the project's epistemic landscape was that between tacit and explicit knowledge. At Leonardo's production sites in Pomigliano d'Arco and Nola, much of the critical operational know-how remains tacit, embedded in the daily practices of operators, engineers and quality managers. This knowledge, passed through imitation, hands-on learning, observation and human interaction, tends to elude formal documentation. Recognizing that such tacit knowledge is particularly vulnerable in accelerated digitization contexts, NEMESI deliberately sought to render parts of it explicit. This was achieved through the production of structured deliverables, the construction of shared digital models such as product lifecycle management (PLM) systems and digital twins, and the deployment of intelligent graphical interfaces that could visually articulate otherwise implicit production processes. The project's documentary infrastructure, as described in its remodeling documentation, functioned as a deliberate bridge between experiential knowledge and formal design codification.

Internally, the project drew on Leonardo's proprietary knowledge assets – process diagrams, line configurations, historical maintenance and inspection data – while also systematically incorporating external expertise. Collaborations with the University of Naples contributed theoretical and methodological insights in areas such as algorithmic design, artificial intelligence and cognitive ergonomics. In addition, small and medium-sized enterprises enriched the project with agile and specialized tools, including metrology simulators, ICT microservice and multisensor interfaces for quality assurance. This configuration highlights how HRM supports not only epistemic integration but also distributed governance. By aligning diverse actors around shared objectives and adaptive interfaces, the project operationalized a form of participatory risk management. This enabled rapid iteration and decision-making across organizational boundaries, embedding KT into both the cognitive and structural dimensions of project governance.

A distinctive feature of the project was its multidisciplinarity, fostering an uncommon hybridity across fields. Mechanical engineering intersected with engineering management; industrial computing engaged with ergonomics and occupational psychology; and additive manufacturing conversed with occupational medicine and safety science. This disciplinary cross-fertilization was enabled by a project organization that fostered integration across operational tasks, ensuring collaboration among teams with diverse knowledge bases. Crucially, this hybrid configuration did not merely support co-presence of disciplines but

enabled their co-evolution over time. The structured-yet-flexible coordination mechanisms intrinsic to HRM allowed teams to iteratively reframe problems, adapt shared vocabularies and generate context-specific solutions. In this way, multidisciplinarity became not just a resource, but a dynamic capability with a key role to navigating the project's high-risk, high-uncertainty environment.

One of the more delicate challenges in such a setting was managing interpretive gaps, or the "translation gap" between what one party intended to communicate and what another understood. To address this, NEMESI used strategies such as shared glossaries, standardized deliverables, academic-industry cross-reviews, and visual tools like flowcharts and drag-and-drop metaphors. These mechanisms did more than streamline communication. Indeed, they allow to operationalize a form of cognitive alignment that was essential to project coherence. By institutionalizing interpretive scaffolds, the project addressed not only semantic mismatches but also deeper epistemic asymmetries.

All of this played out within a highly specific application context: the digitization of the ATR fuselage manufacturing process. Here, knowledge was not abstract but situated, validated through its operational utility within the complex logic of production. The NEMESI project thus treated knowledge not as a static object to be transferred, but as a dynamic process to be co-constructed, maintained, and adapted within an evolving socio-technical environment.

5.2 Knowledge translation mechanisms

KT within NEMESI was conceived not as a linear or unidirectional process, but as a fluid, ongoing activity shaped by tools, interactions and context. These acted as mediators, transforming insights, data and lived experience into operationally viable and shared solutions. Given the complexity of the partnership and the breadth of enabling technologies used, a multimodal, multichannel approach was necessary.

On the formal side, the project relied heavily on structured design artifacts that served as authoritative channels for communication, validation, documentation and collaboration. These included Technology Business Plans for each demonstrator, outlining solutions, performance expectations, technologies, benefits and scaling strategies. Technical-functional roadmaps mapped the evolution of assets over time, marking milestones and interrelations across objectives. All deliverables were standardized with uniform headers, required sections, visual templates, and identification codes, enhancing both interoperability and traceability. Leonardo's PLM systems, extended to include inputs from SMEs and academic partners, centralized product data, design iterations, and quality standards. Process diagrams and BPMN flows further supported the visualization and discussion of complex systems such as smart assembly lines and predictive maintenance protocols. These tools shaped knowledge by embedding validation checkpoints and promoting shared understanding across communities of practice. This allowed the project to maintain coherence without enforcing uniformity, enabling interpretive flexibility within a framework of shared accountability. As such, the KT process was not only distributed, but also reflexively governed through its own artifacts.

However, knowledge was also shaped through social interactions and informal exchanges. Thematic workshops convened in-person on subjects like additive manufacturing and digital twin technologies enabled deep dives by domain experts. Deliverables underwent iterative cross-review, and feedback was systematically discussed and integrated. Technological Test Case (TTC) meetings served as moments of shared evaluation around demonstrators – physical and conceptual "frontier objects" through which diverse actors could align and co-learn. Structured partners such as Deloitte and Leonardo also provided

mentoring and methodological support to smaller organizations, helping to balance power and expertise across the consortium.

Digitally, NEMESI leveraged immersive environments not merely as simulations, but as epistemic tools enabling experiential learning and co-design. Virtual, augmented and mixed reality spaces simulated production settings, facilitated interface testing and allowed users to engage with systems before physical deployment. Digital twins provided real-time, dynamic models of processes and products, and collaborative platforms hosted shared repositories, progress tracking dashboards and co-authoring tools. These practices reflect a move toward knowledge enactment, where learning happens through practical, often hands-on engagement. The combination of physical and digital "learning arenas" enabled a form of distributed sensemaking, where diverse epistemologies could converge through doing rather than just telling. In this light, HRM supported not only risk mitigation, but the cultivation of collective intelligence, transforming the project into a socio-technical infrastructure for continuous learning and adaptive innovation.

Translation across disciplines was perhaps the greatest cognitive challenge. While academic teams framed knowledge in conceptual or theoretical terms, industrial stakeholders sought actionable, performance-driven outputs. To reconcile these differences, NEMESI established hybrid tasks combining academic and industrial actors, adopted visual synthesis tools such as infographics and flowcharts, and formed a cross-disciplinary methodological committee to bridge scientific and engineering approaches.

Narratives also played an important role. Partners employed engineering storytelling techniques to convey the rationale behind design decisions and to elicit empathy and understanding. A notable example involved the testing of an AR module, where differing responses between experienced and novice operators prompted a redesign of the interface. Storytelling in this context served not merely to recount events, but to illuminate the motivations and insights behind specific technical choices.

The KT mechanisms in NEMESI thus operated as a cohesive ecosystem. No single tool or channel acted in isolation; rather, the interplay of artifacts, interactions, environments and narratives enabled a process of co-construction and transformation that added value across all levels of the project.

5.3 Actors and stakeholders

At the heart of the NEMESI project lies a participatory and multilayered structure that brings together a diverse range of stakeholders – industrial, academic, technological and institutional – each with a unique role, domain of expertise and degree of agency. The core challenge was not simply to coordinate these actors, but to establish the structural and relational conditions for a collaborative dynamic that was transformative, sustainable and capable of delivering systemic innovation.

The project consortium was composed of 14 organizations. Leonardo S.p.A., as the lead partner, held operational command over the industrial production context, particularly in aerostructure manufacturing at its Pomigliano and Nola sites, and provided the strategic and methodological leadership that ensured coherence across objectives and activities. Deloitte Consulting played a crucial role as system integrator and knowledge broker, facilitating integration of processes and harmonization of technological architectures, while also mediating between the divergent logics of academia and industry. The University of Naples Federico II contributed as a scientific validator, delivering cutting-edge research methods and acting as a bridge between technical disciplines such as engineering, computer science, ergonomics and human-computer interaction.

Large Enterprises and Specialized SMEs (Hexagon, Essematica, Netgroup, Kineton, Mes Group, Aerosoft, Desa, Protom, HTT Sharpening Center, 3F&Edin and LST) introduced agility, creativity and niche expertise. They were jointly responsible for the digitalization of the product and of the related production processes, developing microservices, software modules, digital learning tools and quality conformity mechanisms for metrology applications and advanced prototypical to test innovations under real operational conditions and to improve plant operators' skills/competences.

Each stakeholder contributed uniquely, influencing both the substance of the work and the decision-making processes. Leonardo, while directing the project's overall trajectory, also shared responsibilities on critical tasks. The Partnership exercised a high degree of autonomy in many areas, acting as agile experimentation hubs. The university held epistemic authority, shaping methodological choices and analytical frameworks, while the governance of the Project ensured coherence across project operational and strategic layers. This distribution of leadership enabled a form of decentralized coordination, balancing structure with flexibility.

Collaboration was structured around nine Work Packages (ORs) and 14 TTCs. Each OR was led by a designated OR Leaders, frequently Leonardo and University of Naples, supported by Task Leaders, spread out among the remaining Partners or university researchers. Within these, TTCs acted as convergence points where knowledge, roles and responsibilities overlapped in the pursuit of concrete solutions. For instance, the TTC focused on digitizing the ATR fuselage manufacturing process brought together Leonardo for infrastructure and logistics, Kineton for quality control interfaces, Hexagon for the digitalization of the work environments, Deloitte and Netgroup for data integration management, and the University for ergonomic design and interface evaluation. These shared spaces of work fostered co-creation through joint data interpretation, collective validation and co-development of technical specifications.

Beyond organizational charts, NEMESI cultivated relational governance mechanisms. Regular coordination meetings ensured alignment, while shared digital spaces enhanced transparency and document traceability. Communication protocols facilitated continuous feedback, and decision-making around major issues, such as project extensions or remodeling, was handled inclusively, reinforcing a sense of collective ownership.

External actors also played an influential though less visible role. The regional Campania production ecosystem stood to benefit from technological transfer and training initiatives. National and European institutions were engaged as evaluators and validators of the project's outcomes. Dissemination activities targeted both the scientific community and the broader industrial sector, aiming to embed the project within a wider system of innovation. In this way, NEMESI functioned not only as a project, but as an agent of territorial transformation.

5.4 Hybrid risk management

In the NEMESI project, risk was not seen as an ancillary concern to be monitored reactively, but as a structural dimension of project design and execution, something to be strategically governed through a hybrid approach that combined formal rigor with adaptive responsiveness.

On the formal side, the project relied on a suite of established risk management tools and frameworks. Project roadmaps and GANTT charts enabled precise planning and early identification of potential bottlenecks. Deliverables were subject to multilevel validations, often involving both task and WP leaders, as well as governance oversight. Interactive dashboards provided real-time status updates with key performance indicators related to timing, quality and workloads. Financial oversight was equally robust, aided by the structure of the Development Contract (CUP), which enabled careful control of eligible costs,

budgeting and reporting. A unique coding system was used to categorize risks according to type – technological, operational, organizational, regulatory or even pandemic-related – along with associated probabilities and impacts.

Alongside this structured system emerged an adaptive practice of risk management shaped by ongoing dialogue and real-time responsiveness. Frequent operational meetings created a culture of openness where problems could be raised early. Task-specific working groups were created to address emergent issues, such as pandemic-related delays or European approval hold-ups. Iterative realignment mechanisms enabled the team to revise plans midstream by launching sprints, reallocating responsibilities or modifying task schedules. Scenario planning introduced fallback options, reducing reliance on rigid timelines or single-point assumptions.

Perhaps the most defining test of this hybrid model came with the onset of the COVID-19 pandemic. The lockdowns disrupted physical access to labs and halted in-person activities during the project's early stages. In response, physical workshops were rapidly restructured into virtual collaborative sessions, experimental phases were postponed in favor of design refinement, and a formal project extension was successfully negotiated. Human resources were rescheduled and priorities reassigned, ensuring the continuity of progress without compromising safety or quality.

This ability to turn crisis into learning exemplified the project's "Hybrid Agile" approach. By blending the structured predictability of the Waterfall model with the iterative flexibility of Agile, NEMESI maintained its strategic coherence while adapting operational practices. This enabled early validation of demonstrators and maintained alignment with evolving conditions and partner feedback.

Importantly, this HRM framework gave rise to organizational learning. Challenges were not seen as isolated anomalies but as opportunities to build resilience. Teams learned to share problems early and openly. The ethos of "fail fast" became embedded, encouraging rapid testing, validation and correction. Lessons learned were systematically documented and folded back into the project knowledge base.

In sum, risk management in NEMESI was not merely about mitigation. It was a transformative enabler that allowed the project to navigate uncertainty while sustaining innovation and continuous learning.

5.5 Knowledge translation outcomes

The outcomes of the KT process in the NEMESI project unfolded across multiple dimensions – technological, organizational, educational, relational and territorial. On a tangible level, the project delivered a set of technological demonstrators that were both functional and scalable. Fourteen full-scale prototypical demonstrators are in course of development and testing to demonstrate the feasibility of the transition to a digital factory in the peculiar industrial sector of the complex aerostructures. These covered a wide spectrum of applications, including the smart assembly processes of ATR fuselages, advanced metrology supported by smart sensors, the digital traceability of components and materials, immersive AR/VR/MR-based training environments, adaptive human–machine interfaces and simulation and optimization tools powered by digital twin technologies. Crucially, these were not isolated prototypes – they were integrated systems installed in real industrial settings, validated through actual use and designed with future scalability in mind.

In parallel, the project produced a new architecture for the digital factory. This model envisions a production environment in which data circulates seamlessly throughout the product lifecycle – from design through manufacturing to inspection and maintenance. Human–machine interactions in this ecosystem are not incidental but are shaped through

ergonomic and cognitive principles. Real-time monitoring and predictive decision-making tools are embedded in the system, enhancing both responsiveness and efficiency. The model has been formalized through detailed technical outputs such as manuals, guidelines and specification documents, with replication in mind.

Another critical output is the creation of an immersive training infrastructure. Designed in collaboration with partners like LST, Kineton, Hexagon and the University of Naples, this platform employs virtual and augmented reality to simulate real production scenarios. It integrates gamification strategies to promote behavioral and technical learning and provides real-time feedback to users. This infrastructure is already in operation, training the human resources involved in the demonstrators and setting the stage for broader workforce transformation.

Beyond these concrete results, NEMESI generated intangible but equally significant outcomes. The project contributed to consolidating the Campania aerospace supply chain by fostering not only technological innovation but also trust-based relationships between large corporations, SMEs, and academic institutions. This relational capital has opened real opportunities for including startups and emerging players and has extended the identity of the project into the broader regional context. The result has been a multiplier effect, strengthening the ecosystem.

From the organizational point of view, the project experimented with and validated a hybrid model of collaboration that combines distributed governance, continuous co-creation, situated leadership and operational horizontality. This model proved effective and is now presented as a benchmark for future public-private innovation initiatives, whether in industrial or educational domains.

The project also generated significant cognitive and cultural capital. Across its lifecycle, NEMESI produced extensive documentation of lessons learned, including those related to pandemic management and project remodeling. The ability of teams to analyze and adapt became a shared asset, enabling reflexive practices and increasing collective resilience. Tools and schemas developed within the project now serve as templates for future efforts.

Finally, the systemic impact of NEMESI extended well beyond its original scope. The project demonstrated that a collaborative approach to digital transition – grounded in effective KT, HRM, resilient partnerships and a systemic outlook – can serve as a replicable and scalable model. In this sense, NEMESI positions itself as a national and European reference point for managing complex innovation challenges in sectors where key enabling technologies intersect with legacy systems, traditional production environments and evolving educational demands.

6. Discussion

The findings allow us to draw rich insights when interpreted through the lens of the integrated theoretical framework cited in the literature. The NEMESI project emerges not only as a strategic endeavor in aerospace innovation but as a paradigmatic case of knowledge-intensive collaboration – one that embodies many of the characteristics found in recent risk and knowledge management scholarship.

At its foundation, NEMESI was designed to tackle the dual challenge of technological complexity and organizational heterogeneity. As Muntés-Mulero *et al.* (2019) point out, such environments demand robust yet adaptive risk management frameworks, as conventional methodologies tend to fall short under conditions of rapid change and uncertainty. Traditional models – characterized by rigid categorization, static assessment and deterministic planning (Hillson and Simon, 2020) –struggle to cope with the evolving risk profile of large-scale innovation ecosystems. Instead, NEMESI applied a HRM model that

reflected the best practices identified by Lai and Lau (2012), blending HHM for systemic awareness, ERM for organizational integration, and risk filtering, ranking and management to prioritize action.

Through this hybrid approach, the consortium was able to implement dual-layered risk strategies: formal tools such as GANTT charts, budget audits and deliverable tracking provided structural control, while agile, real-time mechanisms, including thematic task forces and iterative replanning, enabled a responsive, learning-oriented risk culture (Conforto *et al.*, 2014; Raz and Michael, 2001). This flexibility proved crucial during external disruptions such as the COVID-19 pandemic and internal challenges related to cross-organizational coordination.

Significantly, NEMESI's governance model was distributed and integrative, echoing the propositions of Martyn *et al.* (2016) that less formalized structures enable better balancing of exploration and control. The inclusion of strategic players in the Governance of the Project like Leonardo, Deloitte and University of Naples has been crucial to create a heterogeneous knowledge ecosystem in which power was dispersed, and coordination emerged from shared goals rather than hierarchical mandates. This cooperative configuration aligns with Chapman (1997) and Mikes (2009), who emphasize the need for risk frameworks that embed cognitive and interpretive flexibility, particularly across epistemic divides.

Knowledge within NEMESI was treated not as a static commodity, but as fluid, evolving, and inherently transdisciplinary. This mirrors Nonaka *et al.* (1996) concept of the SECI model - where tacit and explicit knowledge continuously interact through processes of socialization, externalization, combination, and internalization. The project's knowledge management infrastructure supported this dynamism through tools such as shared glossaries, cross-review mechanisms and immersive environments (e.g. AR/VR/MR platforms), which provided experiential translation capabilities. Immersive technologies served as more than visualization aids; they facilitated sense-making and experiential learning, connecting technical experts, managers and researchers.

This is particularly important given that tacit knowledge, often rooted in the embodied practices of industrial actors, poses significant challenges for inter-organizational transfer (Massingham, 2010). NEMESI's approach directly addresses this barrier by transforming tacit insights into actionable knowledge through co-creation workshops, design storytelling and participatory prototyping. These informal methods complemented formal outputs such as PLM systems, supporting the idea that effective KT improves decision-making and practical outcomes.

Furthermore, the project's use of TTCs as sites of convergence for diverse actors exemplifies the kind of practical interventions supported by Temple and Landaeta (2020). TTCs functioned as knowledge integration hubs, where risk insights, technical data and strategic foresight could be combined, validated and deployed. In doing so, NEMESI facilitated a shared cognitive heritage among partners, leading to social capital formation, collective learning and the emergence of replicable innovation models.

From the perspective of organizational resilience, the project's outcomes, ranging from industrial-scale prototype demonstrators to detailed and integrated technology improvements, underscore the power of systemic innovation when supported by integrated risk and knowledge management processes. According to O'Connor *et al.* (2008), successful innovation depends not only on novel technologies but also on the firm's capability to absorb, contextualize and operationalize knowledge across functional and organizational boundaries. NEMESI's integrative architecture enabled precisely that, forging a resilient innovation ecosystem that could adapt to disruption while maintaining coherence.

NEMESI exemplifies the theoretical shift advocated by contemporary scholars from static, siloed risk management toward dynamic, collaborative and knowledge-enabled frameworks. Its success highlights the strategic importance of blending formal governance with agile responsiveness, codified tools with narrative practices and organizational planning with human-centered design. The NEMESI case concretely illustrates how systemic innovation emerges from the interplay of adaptive risk governance and complexity-aware knowledge practices. Drawing on Geels' (2004) and Meadows' (2008) conceptions of socio-technical transitions, the project embodies the transition from linear innovation pipelines to dynamic systems shaped by feedback loops, institutional interplay and multilevel alignment. The application of complexity science, particularly Snowden and Boone's (2007) Cynefin framework, resonates with NEMESI's use of contextual decision-making, wherein risk responses were tailored to specific domains of complexity rather than relying on standardized approaches. In addition, Heylighen's (2001) theory of self-organization and Uhl-Bien and Arena's (2018) work on adaptive leadership highlight how NEMESI fostered emergent coordination and distributed agency through hybrid governance mechanisms. These insights suggest HRM not only supports KT but also drives systemic learning and organizational adaptability. In doing so, the project offers a real-world instantiation of Holland's (1992) vision of complex adaptive systems, where knowledge flows, stakeholder feedback and iterative experimentation converge to shape resilient innovation ecosystems.

In sum, as it can be visually grasped in Table 2 below, NEMESI exemplifies how a strategically orchestrated process of KT, supported by hybrid governance, technological experimentation and human-centered collaboration, can yield not only immediate innovations but also durable transformations in the fabric of industrial ecosystems.

7. Conclusions

This paper has explored the intersection of HRM and KT within the context of complex innovation projects, using the NEMESI project as a paradigmatic case. It contributes to academic literature by bridging two fields – project risk management and knowledge management – that have often developed in parallel but rarely intersected in applied research. By focusing on how HRM enables KT, the paper advances our understanding of how risk governance frameworks can support, not constrain, collaborative knowledge

Table 2. Insights into KT toward innovation under hybrid risk management

Size	Description	Evidence in the NEMESI project
Knowledge characteristics	Nature of tacit/explicit, internal/external knowledge	Operational know-how + academic research; interpretive gap management; common models
Translation mechanisms	Knowledge translation tools	Workshops, technical storytelling, PLM, VR environments, co-design
Actors and stakeholders	Roles and participation of actors	Leonardo (leader), Deloitte (broker), Unina (validator), LE/SME (implementers)
Hybrid risk management	Formal + adaptive risk management	Dashboards, feedback, task forces, alternative scenarios
Translation outcomes	Tangible results of the KT process	Demonstrators, training environments, supply chain impact, replicable ecosystem

Source(s): Authors' own work

creation and innovation, especially in technologically intensive and multi-actor environments.

Theoretically, this paper contributes to the ongoing discourse on the KBV of the firm by positioning HRM not only as a governance mechanism for dealing with uncertainty, but as a dynamic and active enabler of KT. It extends the KBV by showing how HRM structures can foster organizational learning processes through knowledge recontextualization, not merely knowledge transfer. This reconceptualization of HRM as a platform for sensemaking, cognitive alignment and iterative experimentation allows for a more nuanced understanding of how knowledge flows in innovation ecosystems. By bridging the literature on risk management and organizational learning, which have traditionally developed along parallel, rarely intersecting paths, this paper introduces a unified framework that emphasizes the epistemic function of HRM. It shows how HRM practices (e.g. scenario planning, hybrid coordination routines, boundary objects) operate as translation mechanisms that mediate between diverse knowledge domains and stakeholder expectations. Furthermore, the operational framework proposed, with its five interdependent dimensions of knowledge characteristics, translation mechanisms, actor configurations, HRM practices and outcomes, offers both analytical depth and empirical tractability. It provides scholars with a structured lens to capture how KT unfolds in hybrid innovation contexts, particularly in projects marked by high uncertainty, multiple actors and systemic ambition. By combining flexible interpretation with structured governance, the model presents KT as a collaborative process shaped by people, tools and institutions. In this sense, the framework does not merely describe how HRM supports KT, but also theorizes the underlying conditions, structural, cognitive and relational, that enable this process to become a vector of innovation. It thereby adds to the growing literature on hybrid organizational forms, multi-level learning, and knowledge governance in complex projects.

From a practical perspective, the paper delivers valuable insights for project managers, innovation leaders, and organizational strategists. It demonstrates that HRM, when implemented thoughtfully, allows teams to move beyond compliance-oriented risk protocols toward learning-oriented practices. In the NEMESI project, risk was not merely mitigated; it became a driver for experimentation, feedback and strategic alignment. The project's use of TTC, immersive/no-immersive environments and interdisciplinary teams underscores how KT can be embedded in the everyday fabric of collaborative innovation. These findings are highly relevant for organizations operating in sectors where technological complexity, stakeholder diversity and time-sensitive deliverables converge. The model outlined can serve as a blueprint for designing more resilient, responsive and learning-capable project environments. In terms of policy implications, the paper underscores the critical role that public-private consortia and structured innovation programs can play in fostering systemic transformation. NEMESI exemplifies how national and regional industrial policy, when aligned with knowledge ecosystems, can accelerate the digitalization and modernization of legacy sectors. Policymakers can draw from this case to support initiatives that prioritize hybrid governance, cross-sectoral collaboration and workforce reskilling through immersive training infrastructures. Furthermore, the paper provides evidence supporting the value of funding mechanisms that enable iterative learning, flexible replanning and inclusive participation – core elements of adaptive governance that are increasingly vital in the context of fast-paced technological change and geopolitical uncertainty. Importantly, the insights gained from the NEMESI case are transferable to a broader class of complex innovation projects. For project managers, the study provides a model of how to operationalize HRM to foster knowledge co-creation, going beyond compliance-driven approaches. For policymakers, it highlights the strategic role of adaptive governance and knowledge ecosystems in enabling

territorial innovation. The framework can be applied in other contexts involving cross-sectoral collaboration, especially in digital transitions within traditional industries.

In sum, this study makes a multifaceted contribution. It enhances scholarly understanding of how HRM and KT interact; it offers a novel theoretical framing grounded in empirical evidence; it provides actionable insights for practitioners managing innovation under uncertainty; and it informs policy frameworks aimed at fostering agile, knowledge-based industrial transformation. As organizations and governments strive to navigate the complexity of digital innovation ecosystems, the lessons from NEMESI serve as a timely and transferable model.

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Note

[1.] The unique project code is CUP C57H22003220008, and is part of Development Contract CDS000801, approved in 2022 and successfully notified by the European Commission, a comprehensive detailed public description of the project has been notified and reported in https://ec.europa.eu/competition/state_aid/cases1/202346/SA_104370_9078D88B-0000-CE7D-9C8D-45586CF1C918_110_1.pdf

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