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Portfolio Management of Sustainability-Oriented Innovation in Mature Capital-Intensive Industries

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Abstract: This study examines how innovation portfolio decisions concerning sustainability-oriented innovation are made in mature capital-intensive industries. Drawing on a qualitative multiple-case study of nine firms in the Norwegian maritime transport industry, supported by expert interviews and documentary sources, we analyse decision-making across four dimensions: processes, criteria, tools, and participants. The findings show that portfolio decision-making is shaped by high uncertainty, long investment horizons, and strong business-case logic. Portfolio processes are only partly formalized, sustainability considerations gain strongest traction when translated into financial and strategic value, and ownership structure influences time horizon and risk appetite. The study contributes to innovation portfolio management research by developing four propositions and advancing a more context-sensitive understanding of how sustainability-oriented innovation is evaluated and prioritized in mature capital-intensive settings.

Keywords: innovation portfolio management; sustainability-oriented innovation; mature capital-intensive industries; portfolio decision-making; maritime transport

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1 Introduction

Innovation is increasingly critical for firms seeking to secure long-term competitiveness while addressing economic, social, and environmental sustainability challenges (Kuzma et al., 2020; Rubera and Kirca, 2012). Because innovation efforts are constrained by limited resources, firms must continuously decide which initiatives to pursue, postpone, or abandon. This challenge is commonly addressed through innovation portfolio management (IPM), understood as the evaluation, selection, prioritization, and resource allocation of innovation ideas and projects in line with organizational objectives (Cooper et al., 1999; Hansen and Svejvig, 2022; Kock and Gemünden, 2014).

IPM has long been a core topic in innovation research, with much of the literature offering normative guidance on how portfolio decisions should be organized, which actors should be involved, and which tools should be used (Meifort, 2016). Initially developed primarily in the context of physical product innovation, the literature has gradually expanded to other settings, including service innovation, digital innovation, and sustainability-oriented innovation (Aas et al., 2017; Eckert and Hüsig, 2022; Ma et al., 2020). This broader scope has highlighted that IPM practices are contingent on innovation context.

This is particularly important in sustainability-oriented innovation (SOI), where goals are often multifaceted, long-term, and difficult to reconcile with conventional portfolio criteria (Schipper and Silvius, 2018; Martinsuo and Geraldi, 2020). Prior research has therefore focused largely on developing indicators, frameworks, and tools to support sustainability-oriented portfolio decisions (Aghajani et al., 2023; Ma et al., 2020). However, recent reviews indicate a lack of empirical studies examining how firms actually make such decisions in practice (Aghajani et al., 2023; Sabini et al., 2019).

This gap is particularly critical in mature capital-intensive industries. Firms in such sectors typically face long investment horizons, high capital lock-in, and strong path dependencies, conditions likely to shape innovation portfolio decision-making (McGahan and Silverman, 2001; Cillo and Verona, 2022). At the same time, industries such as shipping, aviation, steel, cement, and chemicals are central to contemporary sustainability transitions due to their high emissions and decarbonization challenges (World Economic Forum, 2024). Yet we know relatively little about how sustainability-oriented innovations are selected and prioritized in these contexts.

Against this backdrop, this study explores IPM practices concerning SOI in mature capital-intensive industries. Empirically, we focus on the Norwegian maritime transport industry, an archetypal sector facing a pivotal transition towards decarbonisation. The study addresses the following research question:

> *RQ: How are innovation portfolio management decisions made concerning sustainability-oriented innovation within firms in mature capital-intensive industries?*

2 Theoretical Background and Assumptions

Innovation Portfolio Management (IPM)

IPM refers to the ongoing process through which firms evaluate, select, prioritize, and allocate resources across innovation projects in line with strategic objectives (Cooper et al., 1999; Kock and Gemünden, 2016). Whereas new product development focuses on executing individual projects, IPM concerns "doing the right projects" by managing trade-offs and interdependencies across the portfolio (Ernst and Lichtenthaler, 2009). IPM therefore plays a central role in aligning innovation activities with strategy and ensuring effective use of scarce resources (Meifort, 2016).

A key function of IPM is to balance competing objectives, particularly risk and return, across projects that vary in uncertainty, time horizon, and strategic importance. Broader resource allocation can enhance innovation performance by spreading risk, while selective resource commitment at later stages helps contain costs under uncertainty (Klingebiel and Rammer, 2014). At the same time, established evaluation logics often favour incremental, low-risk projects unless specific organizational arrangements support more radical innovation (Brasil et al., 2021). IPM is thus not merely an analytical exercise, but a dynamic decision-making process shaped by structural and behavioural factors, including strategic clarity, process formalization, organizational climate, and managerial judgment (Kock and Gemünden, 2016; Behrens, 2016).

To capture this complexity, prior research highlights four interrelated dimensions of IPM: process, criteria, tools, and participants (Meifort, 2016; Eckert and Hüsig, 2022). The process dimension concerns how portfolio decisions are structured and updated over time, ranging from formalized systems to more emergent approaches (Kock and Gemünden, 2016; Aas et al., 2017). The criteria dimension refers to the metrics used to evaluate projects, traditionally emphasizing financial returns, strategic alignment, and risk, yet often applied in diverse and inconsistent ways in practice (Behrens, 2016; Aas et al., 2017). The tools dimension includes analytical methods such as portfolio matrices and scoring models, which are widely proposed but not always systematically used (Mikkola, 2001; Eckert and Hüsig, 2022). Finally, the participants dimension highlights the involvement of multiple actors, with top management often playing a central role in strategic prioritization (Martinsuo and Vuorinen, 2022).

Sustainability-Oriented Innovation (SOI)

SOI refers to innovation efforts that intentionally seek to create environmental and/or social value alongside economic value (Adams et al., 2016; Hansen and Grosse-Dunker, 2012). SOI is therefore better understood as an innovation orientation than as a distinct innovation type. It may take the form of product, process, service, organizational, or business model innovation, provided that sustainability considerations are integral to the purpose and expected outcomes of the innovation effort. This broader understanding moves beyond narrow eco-innovation perspectives and emphasizes triple-bottom-line value creation (Adams et al., 2016; Klewitz and Hansen, 2014).

Prior research suggests that SOI is shaped by both internal and external factors. Internally, firms' dynamic capabilities, organizational innovations, and underlying values influence their ability to pursue sustainability-oriented change (Taneja et al., 2023; Rubio-

Andrés and Abril, 2024). Externally, interaction with customers, authorities, research institutes, and other stakeholders may strengthen firms' capacity to develop more proactive and even more radical forms of SOI (Klewitz and Hansen, 2014). Firms also differ in their strategic sustainability orientation, ranging from reactive responses to more proactive and sustainability-rooted approaches (Klewitz and Hansen, 2014).

A central insight in the SOI literature is that sustainability should not be treated as an isolated add-on or final evaluation criterion, but may require changes in organizational philosophy, values, practices, and innovation processes (Adams et al., 2016). SOI, therefore, often involves navigating tensions between established business priorities and emerging sustainability ambitions, sometimes requiring firms to combine different business model or innovation logics over time (Berntsen et al., 2023). For IPM, this implies that SOI is likely to challenge conventional decision logics centred primarily on short-term financial returns and risk.

The context of mature capital-intensive industries

Mature capital-intensive industries are characterized by large, long-lived physical assets, substantial upfront investments, and high adjustment costs. In such settings, competitiveness depends heavily on the performance, utilization, and life-cycle management of existing assets, making operational efficiency, capacity development, reliability, and cost control central managerial concerns (Komonen et al., 2006). Industry maturity does not necessarily imply lower levels of innovation, but it does shape the conditions under which innovation occurs: firms typically innovate within established technological and organizational structures, where specialization, scale, and productivity remain closely tied to accumulated capital and R&D capabilities (McGahan and Silverman, 2001; Tingvall, 2004). Because changes to the asset base are resource-intensive and risky, often involving long development and payback periods, innovation decisions are likely to be more cautious and path dependent than in less capital-intensive settings (Taussig, 2023). Moreover, the implementation of new technologies often requires alignment across infrastructure, engineering processes, monitoring and control systems, and the broader value chain (Adres et al., 2019). These characteristics are particularly consequential for SOI, which often requires substantial changes to core assets and operating systems while offering uncertain and longer-term returns. As a result, IPM in mature capital-intensive industries is likely to be shaped by capital lock-in, operational interdependencies, and the need to balance transformative ambitions with risk management.

Theoretical assumptions

Based on prior research on innovation portfolio management, sustainability-oriented innovation, and mature capital-intensive industries, we derive four theoretical assumptions to guide the empirical analysis. These assumptions are not formal hypotheses, but rather literature-informed expectations concerning how portfolio decisions related to SOI are likely to be organized in capital-intensive contexts.

First, prior IPM research suggests that firms facing large investment commitments and high uncertainty tend to rely on relatively formalized and staged portfolio processes to structure decision-making and limit exposure before committing substantial resources (Kock and Gemünden, 2016; Meifort, 2016). In mature capital-intensive industries, this

logic is likely to extend to SOI, where uncertainty is often amplified by emerging technologies and evolving sustainability requirements (Schipper and Silvius, 2018; Cillo and Verona, 2022). We therefore assume:

> *Assumption 1: In mature capital-intensive industries, portfolio decisions concerning sustainability-oriented innovation are expected to be organized through relatively formalized and staged evaluation processes that enable incremental commitment of resources and systematic management of uncertainty.*

Second, the literature suggests that portfolio decisions are shaped by the criteria used to assess projects (Meifort, 2016; Behrens, 2016). In capital-intensive settings, large sunk costs and limited flexibility imply that individual projects are likely to be scrutinized closely regarding financial viability, strategic relevance, sustainability potential, and risk (McGahan and Silverman, 2001; Schipper and Silvius, 2018). Rather than emphasizing portfolio balance alone, firms may place particular weight on reducing risk within each major investment. We therefore assume:

> *Assumption 2: In mature capital-intensive industries, sustainability-oriented innovation projects are expected to be assessed primarily in terms of financial viability, strategic alignment, sustainability potential, and project-level risk.*

Third, IPM is commonly supported by a range of analytical tools, including portfolio matrices, scoring models, and financial evaluation methods (Mikkola, 2001; Meifort, 2016). In mature capital-intensive settings, where innovation decisions must be justified in concrete business terms, portfolio decisions are likely to rely especially on business cases, financial analyses, and selected sustainability metrics. We therefore assume:

> *Assumption 3: In mature capital-intensive industries, portfolio decisions concerning sustainability-oriented innovation are expected to rely mainly on business cases, financial evaluation methods, and sustainability metrics that make economic and environmental implications visible.*

Fourth, portfolio decisions typically involve multiple actors with different roles and interests (Martinsuo and Vuorinen, 2022; Meifort, 2016). In mature capital-intensive industries, the scale of investments and the importance of technological interdependencies, customer commitments, and regulation suggest that both senior internal decision-makers and key external actors may influence SOI decisions. At the same time, formal approval is likely to remain concentrated at the top management, board, or owner level. We therefore assume:

> *Assumption 4: In mature capital-intensive industries, portfolio decisions concerning sustainability-oriented innovation are expected to involve multiple internal and external actors, while final decision authority remains concentrated among senior decision-makers.*

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3 Method

Research Design

We adopted a qualitative multiple-case study design to explore how innovation portfolio decisions concerning SOI are made in mature, capital-intensive industries (Yin, 2014). A case study approach was appropriate because the study addresses a how-question and seeks to understand portfolio decision-making as a context-dependent organizational process. The study was guided by an abductive logic, moving iteratively between existing literature on IPM and SOI and empirical material from the Norwegian maritime transport industry (Dubois and Gadde, 2002). More specifically, we drew on flexible pattern matching (Bouncken et al., 2021) to compare literature-informed expectations with empirical observations, while remaining open to divergent and context-specific insights.

Case Selection and Sampling

The Norwegian maritime transport industry was selected as a theoretically relevant setting for our research objective. Maritime transport is characterized by large, long-lived physical assets, substantial upfront investments, long payback periods, and high environmental impact, making SOI strategically important and financially demanding (World Economic Forum, 2024; UNCTAD, 2023). Norway is a particularly relevant empirical context as a major maritime nation and an active arena for efforts to accelerate low- and zero-emission shipping.

We used purposive sampling (Patton, 2014) to recruit two complementary groups of informants. The first comprised 10 managers from nine Norwegian-owned or Norwegian-controlled maritime transport firms across five segments, all engaged in ongoing or recently completed emission-reduction innovation projects. Firms were identified through the Green Shipping Programme, industry news, and existing industry contacts. Respondents held executive or senior roles in sustainability, strategy, innovation, risk, or newbuild functions, providing access to actors with influence over strategic decision-making (Harvey, 2011).

The second group comprised 10 industry experts from eight organizations, including sectoral organizations, knowledge environments, and NGOs involved in maritime sustainability and innovation. These informants added broader industry-level perspectives and helped contextualize the firm-level accounts. Together, the sample enabled triangulation between organizational decision-making perspectives and wider field-level insights. An overview of the sample is provided in Table 1.

Table 1 Overview of the informants

Informant	*Firm/Organization # and Type*		*Role/Function*	*Interview mode*
A	1	Offshore Supply	Head of Sustainability	Teams / Recorded
B	2	Chemical Tankers	Chief Executive Officer	Teams / Recorded
C	3	Vehicle Carriers	Risk Manager	In Person / Notes
D	3	Vehicle Carriers	Sustainability Manager	Teams / Recorded

E	4	Chemical Tankers	Head of Sustainability	Teams / Recorded
F	5	Passenger Ferries	Chief Executive Officer	Teams / Recorded
G	6	General Cargo	Head of Strategy	Teams / Notes
H	7	Vehicle Carriers	Project Manager Newbuilds	Teams / Recorded
I	8	Offshore Supply	Head of Sustainability	Teams / Recorded
J	9	General Cargo	Chief Executive Officer	Teams / Recorded
K	10	International NGO	Senior Associate	In Person / Notes
L	11	Innovation Cluster	General Director	Teams / Notes
M	12	Innovation Cluster	Innovation Advisor	In Person / Notes
N	12	Innovation Cluster	Senior Innovation Advisor	In Person / Notes
O	13	Innovation Cluster	Head of Projects	Teams / Notes
P	14	Business Association	Administration Director	In Person / Notes
Q	14	Business Association	Senior Advisor	In Person / Notes
R	15	International NGO	Maritime Lead	Teams / Notes
S	16	Maritime Institute	Professor	In Person / Notes
T	17	Ship Broking	Broker Newbuilds	Teams / Notes

Data Collection

Data were collected from three sources: semi-structured interviews with company managers, informal expert interviews, and documentary material.

The manager interviews were guided by themes related to emission-reduction innovation initiatives, portfolio decision processes, evaluation criteria, actor involvement, and the handling of uncertainty and risk, allowing both comparability and probing across interviews (Myers and Newman, 2007; Harvey, 2011). Most interviews were conducted via Microsoft Teams. Eight interviews lasted between 41 and 75 minutes, were audio-recorded, transcribed using the University of Oslo's secure solution, and subsequently checked and anonymized. In two cases, recording consent was not granted; detailed notes were therefore taken during and immediately after the interview.

We also conducted 10 informal expert interviews with representatives from eight organizations in Norway and international NGOs engaged in maritime sustainability and innovation. These conversations focused on broader industry developments, sustainability challenges, innovation trends, and management practices. They were not recorded, but detailed notes were taken during and after each conversation.

Finally, the interview material was complemented with company annual and sustainability reports, industry reports, and relevant public documents. These were used to contextualize the cases and support triangulation in the analysis.

Data Analysis

The analysis was guided by flexible pattern matching (Bouncken et al., 2021) and proceeded iteratively between prior theory and empirical material. Interview transcripts, interview notes, and documentary sources were imported into MAXQDA and analysed using the four IPM dimensions derived from the literature and the theoretical assumptions:

process, criteria, tools, and participants. These dimensions provided an initial analytical framework, while the coding remained open to context-specific insights.

Particular attention was paid to how portfolio decision-making was shaped by the characteristics of mature capital-intensive settings. The material was compared across interviews, firms, and data sources, and the emerging insights were summarized in cross-case matrices in Excel to support systematic comparison of recurring patterns and differences. This iterative movement between literature-informed expectations and empirical observations enabled us to examine and refine the initial assumptions. The analysis was led by the first author and discussed within the research team to strengthen the credibility of the interpretations.

4 Findings

The empirical material provides insights from nine Norwegian maritime transport firms operating in both deep-sea and short-sea segments. The sampled firms had engaged in different types of emission-reduction innovation projects, including energy-efficiency measures, investments in alternative and lower-emission fuels, and exploration of end-of-pipe solutions. While the companies differed in segment, scale, and project portfolios, the analysis also revealed recurring patterns in how SOI projects were evaluated, prioritized, and advanced.

In the following, the findings are presented in relation to the four theoretical assumptions that guided the analysis.

Portfolio processes

Our findings underscore that portfolio decision-making concerning SOI is strongly shaped by uncertainty and risk. Across the cases, informants pointed to several industry-specific conditions that complicate investment decisions: high cost of immature technologies, long vessel lifetimes and investment horizons, uncertain future fuel availability and infrastructure, lagging regulation, short-term customer contracts, and limited willingness to pay for greener solutions. In this context, SOI decisions were often framed less as straightforward investment choices and more as difficult strategic bets. As the project manager of firm 7 explained:

> "How to make that choice and what, almost, to bet on? Because there's so much uncertainty... Building a vessel now, it is a bet, it is a challenge."

A recurring response to this uncertainty was to emphasize risk mitigation throughout the decision process. Several firms sought to reduce exposure by prioritizing smaller energy-efficiency measures, investing in hybrid solutions, or building in flexibility for future retrofits rather than committing fully to one technological trajectory. The ship broker from organization 17 noted this was an industry-wide trend, while the sustainability manager of firm 3 emphasized:

> "But it's all risk management, right? Because these are expensive mistakes to make."

At the same time, the findings indicate that portfolio processes were often less formalized than assumed. Informants described recurring activities such as identifying relevant solutions, assessing feasibility, gathering information on costs, benefits, risks, and

regulatory implications. However, these activities were rarely embedded in highly structured stage-gate systems. Only one company explicitly described the use of a formal stage-gate process. Others referred more loosely to iterative internal discussions and final "go/no-go" decisions. As the CEO of firm 2 put it:

> "So it's a process, but it's not like a method, or it's not like a document... But I mean, of course, we have a process when we do it."

Finally, major investment decisions were typically escalated to executive management, boards, or owners for approval. Thus, although portfolio processes often unfolded through iterative assessments and informal interaction, final commitment authority was usually concentrated at the top of the organization. Overall, the findings suggest that portfolio processes in this context are best characterized as risk-oriented, iterative, and only partly formalized. Rather than strongly supporting the assumption that SOI would be managed through formalized staged processes, the findings indicate a greater reliance on pragmatic, evolving, and interaction-driven decision processes.

Decision criteria

Our findings show that SOI projects are typically assessed using business cases that combine financial, strategic, and sustainability-related considerations. Across the cases, informants emphasized that major investment decisions require a clear justification of why a project makes sense, usually in terms of expected costs, benefits, risks, and broader strategic relevance. In practice, this meant that financial viability remained a central decision criterion. As the project manager of firm 7 explained:

> "For us it all boils down to the business case ... We have to be really careful in the capital expenditures. So that is limiting us in our ability to make those kinds of investments. So that's why it just boils down to business case."

At the same time, the findings show that evaluating project-level risk is a key part of these business cases. In addition to conventional financial and operational risks, firms were concerned with uncertain future fuel availability, technological uncertainty, and the risk of investing in solutions that might later prove unviable. A further and highly important consideration was whether costs and risks could be shared across the value chain. Here, differences in contract structures appeared particularly consequential. Firms operating with longer-term customer commitments seemed better positioned to justify capital-intensive sustainability investments, whereas firms relying on short-term contracts often had to bear more of the risk themselves. This suggests that portfolio decisions are shaped not only by project attributes, but also by the commercial and contractual conditions surrounding them.

The findings also indicate that sustainability value increasingly forms part of decision criteria, despite being more difficult to assess in tangible terms. Firms referred to indicators such as carbon-intensity reduction, CO2 savings, and reduced fuel consumption, typically linked to strategic decarbonization targets and transition plans. Several informants noted, however, that the sustainability effects of prospective initiatives were often based on estimates rather than robust evidence. As the CEO of firm 2 stated:

> "Before you could just have like a return on investment analysis ... But now, how are you going to assess that? How green is your fleet and how much is it going to give you on customer value? It's difficult to assess, so you have to just make an estimated guess."

Although sustainability considerations were clearly present, the findings suggest that they gained the strongest traction when they could be translated into economic terms. Fuel savings, lower compliance costs, avoided carbon costs, customer premiums, or potential revenues from surplus carbon credits all made sustainability arguments easier to incorporate into investment decisions. In this sense, sustainability and economic value were not always treated as separate criteria, but often combined within the same evaluative logic. As the sustainability manager of firm 3 noted:

> "One thing that maybe helps out now is with EU ETS and FuelEU Maritime, you can actually put a dollar value on CO2 ... and it facilitates that discussion."

Overall, the findings suggest partial support for the assumption that SOI projects need to demonstrate both financial value and sustainability potential. However, rather than sustainability and economic criteria being weighed as separate and equally strong dimensions, the findings indicate that sustainability considerations often became most influential when they reinforced, or could be reframed in terms of, financial and strategic value. Portfolio decision criteria in this context therefore appear to be shaped by a strong business-case logic, within which sustainability concerns are increasingly incorporated but not always independently decisive.

Tools

Our findings suggest that portfolio decisions concerning SOI are supported primarily by a combination of financial evaluation tools, risk analyses, and selected sustainability assessment methods. Across the cases, informants referred most frequently to established financial tools such as return on investment (ROI), net present value (NPV), cost-benefit analysis, and financial forecasting. These were commonly used to assess whether a project could be justified economically under different assumptions. In parallel, firms also used scenario-based analyses and various forms of risk assessment to explore the longer-term implications of investment choices, particularly in relation to uncertain fuel developments, future regulation, and market conditions. As the CEO of firm 2 explained:

> "We can try to calculate ... make scenarios in terms of what will the ETS cost be and what will be the impact on FuelEU Maritime and your fleet ... so we get help ... to make models to calculate future scenarios."

Compared with the economic dimension, the tools used to assess sustainability value appeared less standardized. Informants referred primarily to calculations and estimates of CO2 reductions, carbon intensity, fuel savings, and, in a few cases, life-cycle assessments. These assessments were often linked to broader decarbonization plans, transition models, or strategic emission-reduction targets, which helped position individual investments within a longer-term sustainability trajectory. Only one company explicitly referred to a scoring tool for ranking initiatives, and it was used mainly to shortlist energy-efficiency measures based on technical feasibility rather than for broader portfolio optimization.

The findings also suggest that tools played an important communicative role in the decision-making process. Several informants emphasized that complex technical and sustainability-related information had to be translated into formats meaningful to executive management and boards. In practice, this meant that business cases, board memos, executive summaries, and transition plans often functioned not only as analytical instruments, but also as devices for framing and legitimizing investments. As the CEO of firm 9 pointed out:

> "The most important part of any report is the executive summary."

Overall, the findings suggest partial support for the assumption that portfolio decisions would rely on financial and sustainability-related tools. However, rather than reflecting a highly formalized or standardized toolset, the empirical material points to a pragmatic combination of established financial analyses, scenario-based risk assessments, and simpler sustainability calculations. Moreover, tools appear to matter not only because they evaluate projects, but also because they make complex investments understandable and actionable for key decision-makers.

Participants in portfolio decision-making

Our findings demonstrate that portfolio decision-making concerning SOI typically involves a broad set of internal actors, while final authority remains concentrated at the top of the organization. Across the cases, informants described close interaction among technical and operational teams, newbuild functions, sustainability staff, finance and commercial units, risk and compliance personnel, and, in some instances, external consultants. These actors contributed different forms of expertise and information to the preparation of investment cases. In most firms, however, the responsibility for compiling this information and advancing projects toward approval rested with executive managers or project-responsible individuals in technical, sustainability, or newbuild roles. As the sustainability manager of firm 3 explained:

> "We have our project group ... involvement from all the required levels in the organization. And then, of course, the top-level management will be heavily involved with our board ... when we're finally going to make the decision."

The findings also indicate that different functions shaped the decision process in distinct ways. Sustainability roles, in particular, appeared to have become more prominent in several firms. Informants in such positions described their role as contributing knowledge about regulatory developments, future-proofing, and emerging technologies, as well as promoting projects and influencing how alternatives were framed. More generally, participants not only provided information; they also challenged assumptions, negotiated priorities, and helped define what constituted a credible investment case. This suggests that portfolio decisions were shaped not only by formal authority, but also by the ability of particular actors to interpret sustainability challenges and translate them into strategically relevant terms.

At the same time, executive management and boards were typically described as the key approval bodies for major investments. Boards typically reviewed the material prepared by management, raised questions, and gave formal authorization, while executive teams often acted as intermediaries between project-level actors and final decision-makers. Several informants also noted that personal attributes of senior decision-makers, such as experience, beliefs, competence, and sustainability mindset, could influence both the pace and direction of investment decisions. Thus, even where formal governance structures were in place, decision outcomes were not purely procedural, but also shaped by judgment at the top.

A particularly important finding concerns the role of ownership structure. Several informants, both managers and industry experts, suggested that privately owned firms were often able to make decisions more quickly and take a longer-term view than publicly listed firms, which were perceived as more constrained by governance routines, capital market pressures, and shorter-term performance expectations. Family ownership appeared

especially consequential in some cases. Owners or family representatives on boards actively shaped investment priorities and were described as willing to support SOI based on long-term values or legacy considerations. As the sustainability director of firm 8 noted:

> "Those ship owners that are taking the most risk on this, seem to me to be the privately owned ones."

Overall, the findings support the assumption that SOI decisions in mature capital-intensive industries involve multiple actors and perspectives. At the same time, they refine this expectation by showing that influence is not evenly distributed: while many actors contribute to developing investment cases, formal decision authority is concentrated among senior executives, boards, and, in some firms, owners. Moreover, ownership structure appears to shape not only who participates, but also the time horizon and risk appetite underpinning portfolio decisions.

5 Discussion and conclusions

The empirical analysis highlights how the context of SOI in mature capital-intensive industries shapes innovation portfolio decision-making. In the following, we discuss the findings in relation to the initial theoretical assumptions and develop propositions for each of the four IPM dimensions, thereby identifying implications for theory development and future research.

Portfolio processes

Our first theoretical assumption suggested that portfolio decisions concerning SOI in mature capital-intensive industries would be organized through relatively formalized and staged evaluation processes that enable incremental commitment of resources and systematic uncertainty management. The findings provide only partial support for this assumption. Consistent with prior IPM research, decision-making was strongly shaped by uncertainty, risk, and the need to manage major resource commitments carefully (Meifort, 2016; Kock and Gemünden, 2016). The more unexpected finding is that these conditions did not lead to highly formalized portfolio processes. Rather, firms relied on recurring but only partly formalized evaluation activities, and on iterative interaction among managers, technical experts, and senior decision-makers.

This contrasts with more normative IPM assumptions that high-stakes innovation contexts require structured evaluation processes to improve decision quality (Kock and Gemünden, 2016). Instead, our findings suggest that when SOI is characterized by long time horizons, immature technologies, and limited evaluative precision, uncertainty is managed more through pragmatic adjustment, cautious sequencing of investments, and interaction-driven judgment than through formalized portfolio routines. This extends prior research emphasizing that portfolio management practices are contingent on innovation context (Eckert and Hüsig, 2022; Aas et al., 2017).

Consequently, we propose:

Proposition 1: In mature capital-intensive industries, portfolio decisions concerning sustainability-oriented innovation are likely to be organized through iterative and only partly formalized evaluation processes, in which uncertainty is managed through cautious sequencing of commitments and close interaction among key decision-makers.

Decision criteria

Our second theoretical assumption posited that SOI projects in mature capital-intensive industries would be assessed primarily regarding financial viability, strategic alignment, sustainability potential, and project-level risk. The findings provide partial support for this assumption. Consistent with prior IPM research, portfolio decisions were strongly shaped by business-case considerations, including expected returns, cost implications, strategic relevance, and risk exposure (Meifort, 2016; Behrens, 2016).

Sustainability potential was also increasingly considered, often through carbon reduction targets, fuel savings, and emissions-related indicators, in line with SOI research emphasizing that innovation decisions extend beyond purely economic considerations (Adams et al., 2016; Schipper and Silvius, 2018). However, the more unexpected finding is that sustainability considerations gained strongest traction when they could be translated into economic and strategic value, for example through fuel savings, avoided compliance costs, or stronger long-term competitiveness. Rather than operating as a separate decision logic, sustainability was often absorbed into an expanded business-case logic. This suggests that, in mature capital-intensive industries, sustainability criteria become influential primarily when they reinforce financial and strategic rationales.

Therefore, we propose:

> *Proposition 2: In mature capital-intensive industries, sustainability-oriented innovation projects are most likely to gain portfolio support when their sustainability potential can be translated into financial and strategic value within a broader business-case logic.*

Tools

Our third theoretical assumption suggested that portfolio decisions concerning SOI in mature capital-intensive industries would rely mainly on business cases, financial evaluation methods, and sustainability metrics that make economic and environmental implications visible. The findings provide partial support for this assumption. As expected, established financial tools such as ROI assessments, cost-benefit analyses, and scenario-based forecasting played a central role in evaluating major investments, consistent with prior IPM research (Meifort, 2016; Mikkola, 2001).

However, sustainability aspects were rarely assessed through distinct or highly standardized tools. Instead, they were typically embedded within broader business cases, commercial analyses, transition plans, or scenario models, in contrast to literature emphasizing sustainability indicators and formal decision-support frameworks (Schipper and Silvius, 2018; Ma et al., 2020). An unexpected finding is that tools also played an important communicative role by helping senior decision-makers understand the long-term implications and strategic relevance of uncertain investments. Thus, tools functioned not only as evaluation mechanisms, but also as devices for translating sustainability-oriented investments into credible investment cases.

Accordingly, we propose:

> *Proposition 3: In mature capital-intensive industries, tools used in portfolio decisions concerning sustainability-oriented innovation are likely to function not only as evaluation mechanisms, but also as communicative devices that help translate long-term sustainability implications into strategically meaningful investment cases.*

Participants in portfolio decision-making

Our fourth theoretical assumption suggested that portfolio decisions concerning SOI in mature capital-intensive industries would involve multiple internal and external actors, while final decision authority remained concentrated among senior decision-makers. The findings largely support this assumption. Consistent with prior IPM research, a broad set of internal actors contributed technical, operational, financial, commercial, sustainability, and compliance-related perspectives to the preparation of investment cases, while external actors, particularly customers and regulators, shaped the commercial and institutional conditions under which investments were evaluated (Meifort, 2016; Martinsuo and Vuorinen, 2022).

At the same time, participation did not imply equal influence. Final authority was typically concentrated at the level of executive management, boards, or owners. An unexpected finding is that sustainability functions and ownership structures appeared to shape decisions in particularly important ways. Sustainability roles contributed regulatory awareness and future-oriented framing of technological options, while ownership structure influenced time horizon and risk appetite. Privately owned and family-influenced firms were often perceived as more willing to support long-term sustainability-oriented investments than publicly listed firms facing stronger short-term constraints. This suggests that participants in portfolio decision-making should be understood not only in terms of formal involvement, but also in relation to governance context and ownership logics.

Therefore, we propose:

> *Proposition 4: In mature capital-intensive industries, portfolio decisions concerning sustainability-oriented innovation are likely to involve broad participation in the preparation and framing of investment cases, while final decision authority remains concentrated among senior decision-makers, with ownership structure shaping time horizon, risk appetite, and the relative influence of different actors.*

Theoretical contribution

This study contributes to the IPM literature by showing how portfolio decisions concerning SOI are shaped by the specific conditions of mature capital-intensive industries. While prior research has often provided normative guidance on portfolio structures, criteria, and tools, our findings show that decision-making in this context is more pragmatic, interaction-driven, and contextually embedded than such models typically imply (Meifort, 2016; Eckert and Hüsig, 2022).

More specifically, the study makes three contributions. First, it shows that portfolio processes remain only partly formalized even in high-stakes investment settings, with uncertainty often managed through iterative interaction and cautious sequencing of commitments rather than through highly structured evaluation systems. Second, it shows that sustainability considerations tend to gain decision-making traction when they can be translated into financial and strategic value, suggesting that sustainability is often incorporated into an expanded business-case logic rather than operating as a separate evaluative logic. Third, it highlights the importance of governance context, particularly ownership structure, in shaping time horizon, risk appetite, and the relative influence of different actors in portfolio decisions. Together, these contributions point to the need for a

more context-sensitive understanding of innovation portfolio management for sustainability-oriented innovation.

Practical implications

The findings offer several implications for managers in mature capital-intensive industries seeking to increase investments in SOI. Such investments cannot be managed effectively through standard evaluation routines alone. Given high upfront costs, long payback periods, and considerable uncertainty, managers need decision processes that allow for iterative assessment, cautious sequencing of commitments, and close cross-functional dialogue.

The findings also highlight the importance of communication in advancing sustainability-oriented investment cases. Projects need to be translated into credible business cases supported by clear assumptions, scenario analyses, and understandable representations of long-term risks and opportunities, particularly where final authority rests with executive management, boards, or owners. Managers should also recognize that portfolio decisions are shaped not only by project characteristics, but also by governance conditions such as ownership structure, internal role distribution, and the influence of the sustainability function. Although the study focuses on maritime transport, these implications are also relevant for other mature capital-intensive sectors facing sustainability transitions.

Limitations and future research

This study has several limitations. First, it is exploratory and based on a limited number of firms and informants within one national and industrial context. The findings therefore provide analytically relevant insights rather than statistically generalizable conclusions. Second, the sampled firms were selected because they had engaged in recent emission-reduction innovation projects and agreed to participate, which may mean that the study captures relatively active or forward-leaning firms in the sustainability transition.

These limitations also suggest directions for future research. Further studies could examine portfolio decision-making for SOI across a broader range of firms, sectors, and national contexts. Comparative research could be particularly valuable in exploring how ownership structures, governance arrangements, and strategic sustainability orientations shape decision-making. Future research could also investigate how such practices evolve over time as firms gain more experience with sustainability transitions and low- and zero-emission technologies. More generally, the propositions developed in this study may serve as a basis for further qualitative and quantitative work on innovation portfolio management in mature capital-intensive industries.

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