From Technology to Market:

A Systematic Approach to Problem-Solution Fit in Deep-Tech Commercialisation

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Preface

The idea for this thesis started with my curiosity about how innovative technologies can transition from being exciting ideas to practical, impactful solutions. When I came across Docklab and their digital twin technology, NexTwin, I was struck by how clear the technology was to its founders, but how unclear the technology and its benefits were to everyone I tried to explain it to. This inspired my focus on tackling the “solution looking for a problem” dilemma that many deep-tech ventures face.

Throughout this project, I experienced both challenges and growth. I learned how to manage uncertainty, embrace setbacks, and adapt my goals. A significant turning point was realising that finding a client for NexTwin was not feasible within the scope of my research. While this was disappointing at first, it led me to focus on creating a replicable process to help ventures systematically identify and validate problem areas. This shift gave the project a broader relevance, and I am proud of the result.

I want to thank my supervisors, Erik-Jan and Jeroen, for their invaluable guidance and support. Your approachable and informal style made our discussions feel more like collaborative brainstorming sessions than formal supervision. This natural way of working not only encouraged me to think critically but also made the process so enjoyable that I sometimes forgot I was working on my graduation project.

I am also grateful to Docklab for welcoming me into their team and giving me access to their expertise and resources. A special thanks to all the stakeholders who participated in the Reverse Hackathon and shared their valuable insights; it wouldn’t have been possible without your contributions. Finally, I want to thank my family, Lucas, and my friends for their encouragement and for helping me stay grounded during the stressful moments.

This thesis has taught me a lot about deep-tech commercialisation and how strategic design can help bridge the gap between technology and real-world applications. I hope the process developed here can help other ventures navigate the early challenges of aligning technology with market needs.

Thank you for reading, and I hope you find this research as insightful as I found the process of creating it.

Zora Schiferli

07.02.2025

Executive Summary

Deep-tech ventures, such as those developing digital twins, artificial intelligence, or blockchain solutions, often struggle to connect their innovative technologies with clear, actionable market opportunities. Unlike single-product start-ups that address well-defined customer pain points, deep-tech ventures are often driven by technological innovation in search of practical applications. This “solution looking for a problem“ scenario hinders commercialisation, as many ventures fail to establish a direct link between their technologies and specific, solvable problems.

This thesis tackles this challenge by proposing a systematic Problem-Solution Fit (PSF) process tailored to deep-tech ventures. The PSF process helps to identify, prioritise, and validate problem areas, bridging the gap between technological potential and market relevance. The study was conducted in collaboration with Docklab, a venture lab exploring commercialisation for NexTwin, a digital twin technology. The research combined a literature review, case study analysis, semi-structured interviews and an emerging method called a “Reverse Hackathon”.

The research highlights three key obstacles that hinder Problem-Solution Fit in deep-tech ventures. First, stakeholder engagement is difficult in multi-stakeholder environments due to conflicting priorities, trust issues, and fragmented data ecosystems. Second, integration challenges arise from legacy systems, high adoption costs, and the perceived complexity of advanced technologies. Third, ventures face strategic tensions between market-pull and tech-push approaches, creating uncertainty in balancing their innovative potential with practical industry needs.

These insights informed the development of the PSF process, which includes three phases: exploration, validation, and decision-making. Tools like stakeholder mapping and assumption mapping help to identify actionable problem areas, while the Reverse Hackathon serves as a central activity to uncover hidden industry pain points and validate priorities. By prioritising actionability, stakeholder alignment, scalability, and market relevance, the process provides a structured path for deep-tech ventures to transition from abstract innovations to market-ready solutions.

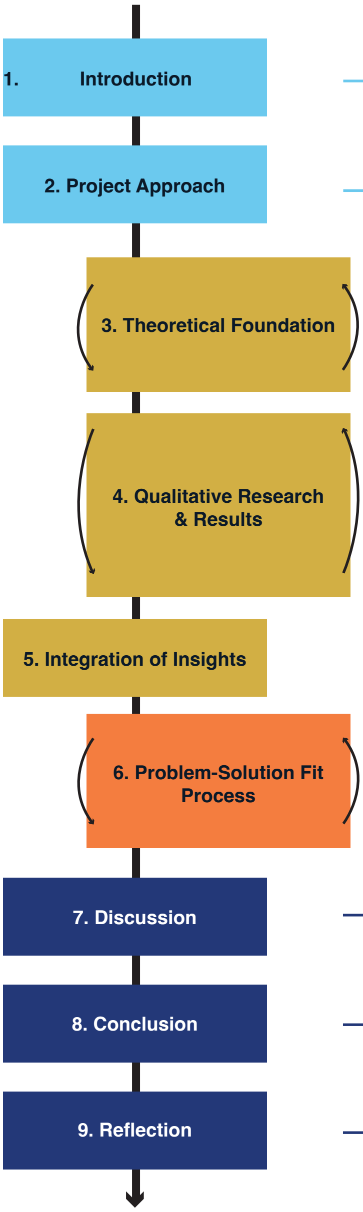
The Docklab case study revealed critical lessons. While the Reverse Hackathon generated three actionable problem areas and direct client leads, internal challenges, such as reactive outreach and broad value propositions, prevented these opportunities from being pursued. This highlighted the importance of focus, proactive stakeholder engagement, and sector-specific value propositions for deep-tech ventures. The process demonstrated its effectiveness in identifying and prioritising problem areas while underscoring the need for refined commercialisation strategies.

This research contributes to academic literature and practice by extending frameworks like Romme et al.’s (2023) Reverse Hackathon to focus on early-stage PSF in tech-push contexts. The PSF process provides a replicable methodology for navigating ambiguous markets, enabling collaboration, and aligning technological capabilities with market needs. Its interdisciplinary design, integrating sociology, cognitive science, and design thinking, enhances its adaptability across industries.

For practitioners, the PSF process offers actionable tools to reduce false starts, allocate resources efficiently, and align innovations with stakeholder priorities. Although developed in the Docklab context, the process is scalable and adaptable, offering a valuable framework for ventures addressing the “solution looking for a problem” dilemma. By achieving PSF, ventures can navigate uncertainty, build stakeholder trust, and establish a foundation for sustainable market success.

Reading Guide

This thesis is organised into nine chapters, each contributing to the overarching goal of developing a systematic process for achieving Problem-Solution Fit (PSF) in deep-tech ventures. This structure ensures a logical progression from defining the problem to proposing a solution, making the thesis accessible and relevant for both academic and industry audiences.



Introduction

Established the context, research aim, and scope of the study, highlighting the challenges faced by deep-tech ventures in achieving PSF and outlining the research questions driving this thesis.

1

Project Approach

Explains the research methodology, including the design science approach and the extended single case study of NexTwin, detailing how multiple methods were integrated to generate insights.

2

Theoretical Foundation

Synthesises existing literature on deep-tech commercialisation, identifying key gaps and limitations in current frameworks for problem-area discovery and validation.

3

Qualitative Research

Presents the empirical findings from the case study, including insights from interviews and the Reverse Hackathon, and highlights patterns that inform the development of a PSF process.

4

Integration of Insights

Develops criteria for prioritising and validating problem areas, based on theoretical and empirical findings, to guide ventures in aligning their innovations with actionable market needs.

5

Problem-Solution Fit Process

Propose a structured PSF process tailored to the unique challenges of deep-tech ventures, integrating the developed criteria and empirical insights.

6

Discussion

Reflects on the implications of the research findings, situating them within the broader academic and practical discussions on deep-tech commercialisation.

7

Conclusion

Summarises the key findings, revisits the research questions, and outlines the contributions and limitations of the study, as well as directions for future research.

8

Reflection

Provides a critical reflection on the research process, methodology, and personal learnings, with an emphasis on challenges encountered and lessons for future research.

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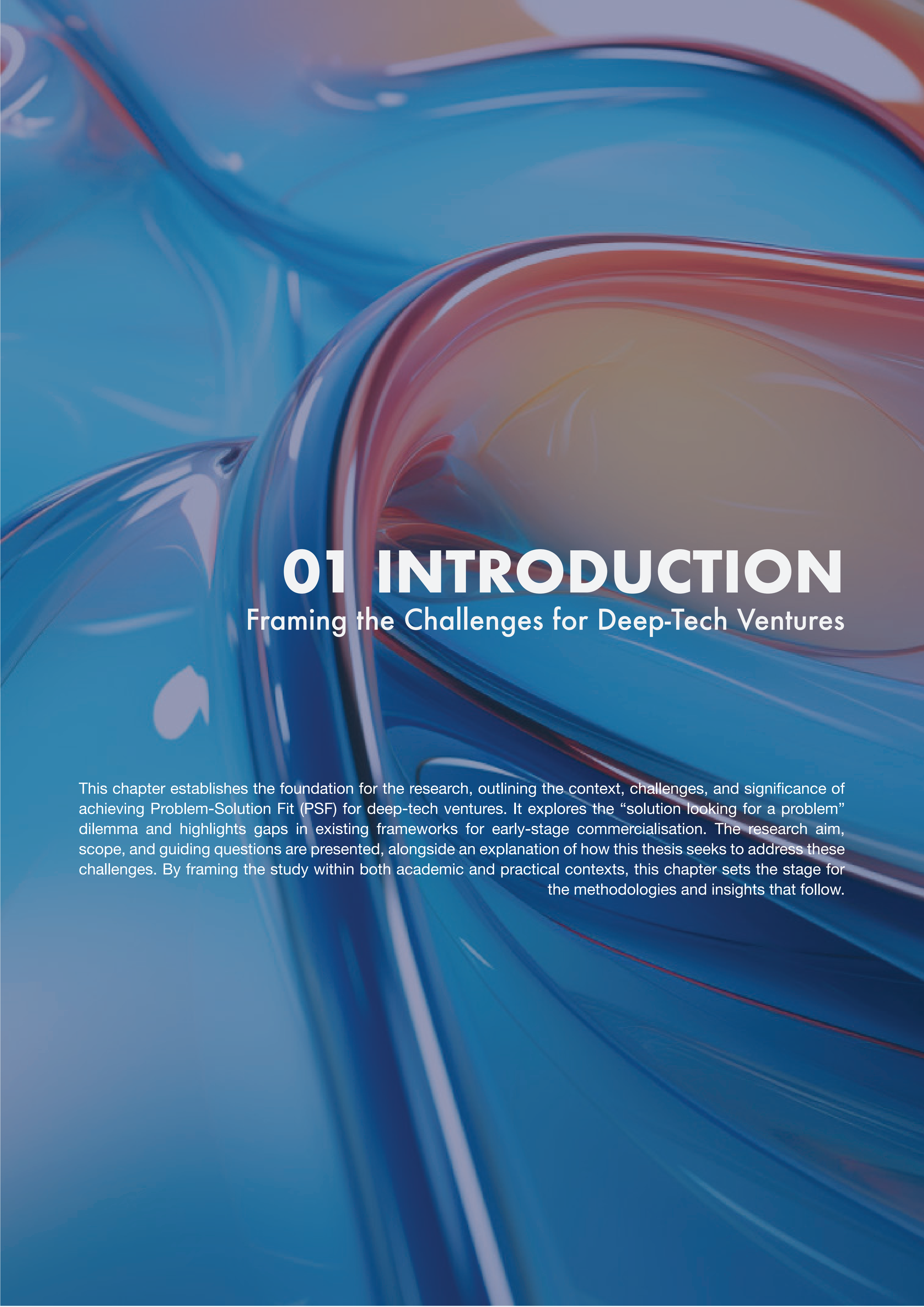


01 INTRODUCTION

Framing the Challenges for Deep-Tech Ventures

This chapter establishes the foundation for the research, outlining the context, challenges, and significance of achieving Problem-Solution Fit (PSF) for deep-tech ventures. It explores the “solution looking for a problem” dilemma and highlights gaps in existing frameworks for early-stage commercialisation. The research aim, scope, and guiding questions are presented, alongside an explanation of how this thesis seeks to address these challenges. By framing the study within both academic and practical contexts, this chapter sets the stage for the methodologies and insights that follow.

1.1 The Deep-Tech Commercialisation Dilemma

Deep-tech ventures represent the forefront of technological innovation, containing fields such as digital twins, artificial intelligence, and blockchain. These technologies have the potential to transform industries, yet their commercial success is far from guaranteed. Unlike traditional start-ups, which often address pre-identified market needs, deep-tech ventures are frequently driven by technological advancements developed without predefined applications. This disconnect creates what *Leiva & Kuschel (2020)* describe as the “**solution looking for a problem” dilemma**, where innovative technologies struggle to align with validated market demands (see Figure 1).

Research indicates that the inability to achieve this alignment is a significant factor in the high failure rates of innovation-driven start-ups. Survival rates for such ventures remain low, averaging below 20% in Europe (Statista, 2018). The Organisation for Economic Co-operation and Development (OECD, 2021) further highlight the role of market alignment and entrepreneurship ecosystems in overcoming these challenges. For deep-tech ventures, prolonged development cycles, technical complexity, and ambiguous market demand amplify the difficulty of achieving Problem-Solution Fit (PSF), a foundational step toward commercial success.

Absence of Frameworks

Commercialisation frameworks such as Lean Startup *(Ries, 2011)* and Business Model Canvas *(Osterwalder & Pigneur, 2011)* are owidely used by traditional ventures. However, these methods assume a baseline understanding of market segments or target users, which deep-tech ventures often lack. While these approaches emphasise iterative validation and customer-centric design, they provide limited guidance for ventures that are still defining potential problem areas.

This gap is especially critical for deep-tech ventures. Unlike consumer tech or conventional single-product start-ups, where customer needs are relatively well-defined, deep-tech ventures must first identify how their technological capabilities can create measurable value before advancing to broader commercialisation efforts.

Defining Problem Areas

In this thesis, poblem areas refer to unmet needs, inefficiencies, or opportunities within industries that could benefit from the application of emerging technologies *(Blank, 2013)*. Identifying these areas is a critical step for deep-tech ventures to align their innovations with real-world demands. However, existing commercialisation frameworks offer limited guidance for systematically identifying, prioritising, and validating these areas.

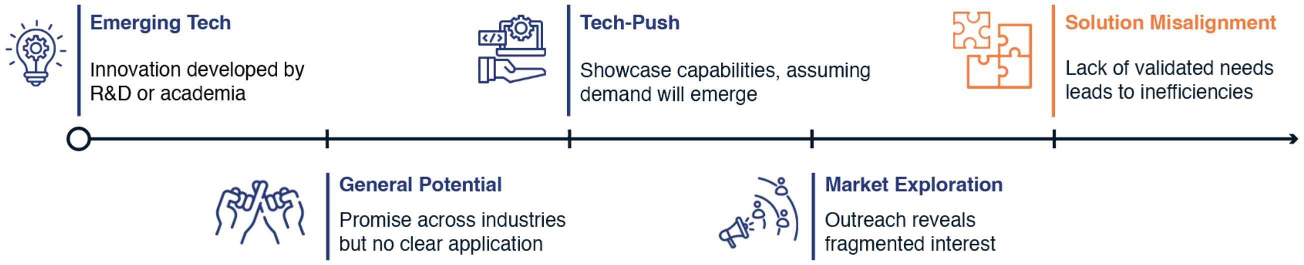


Figure 1. Timeline from Technological Breakthrough to “Solution Looking for a Problem“ Dilemma

Without a structured approach, many ventures resort to improvised or passive methods, such as generic market outreach. These approaches often fail to yield actionable insights, leading to investments in misaligned solutions that lack stakeholder relevance. This misalignment can hinder adoption, limit market impact, and ultimately risk commercial success. Therefore, there is a pressing need for methodologies that help ventures systematically uncover and validate problem areas to establish a foundation to sustainble commercialisation.

The Role of Problem-Solution Fit (PSF)

Problem-Solution Fit (PSF) is an essential early-stage milestone for aligning technological innovation with market needs. Grounded in principles of innovation management, PSF ensures that a product or technology addresses a validated and significant problem before scaling efforts toward broader market-fit initiatives *(Blank, 2013; Christensen, 2007)*.

For deep-tech ventures, achieving PSF is particularly important due to their unique challenges. These ventures face prolonged development cycles, technical complexity, and high levels of market uncertainty *(Haessler et al., 2020*). Without PSF, ventures risk allocating resources to technologies that lack stakeholder relevance, delaying adoption and commercial success. By focusing on PSF, ventures can build a stronger foundation for addressing market demands, improving stakeholder alignment, and reducing the risks associated with early-stage commercialisation.

This thesis introduces a tailored PSF process to address the challenges posed by the "solution looking for a problem" dilemma. Unlike existing frameworks, which often assume a clear understanding of market segments, the PSF process emphasises the systematic identification, prioritisation, and validation of problem areas.

The proposed PSF process aligns with *Markham's (2002)* call for structured decision-making and proactive stakeholder engagement as essential elements for guiding ventures toward market readiness. By integrating these principles, the process ensures that technological innovations are evaluated against real-world needs, enabling ventures to move from exploration to actionable solutions (see Figure 2).

By addressing the challenges of deep-tech commercialisation, this thesis contributes a replicable framework that not only helps ventures achieve PSF but also lays the groundwork for sustainble market success. The following section outlines the research aim and scope, detailing how this study investigates and refines the PSF process to support ventures in overcoming the complexities of early-stage market alignment.

Figure 2. Research Scope

1.2 Research Aim and Scope

Building on the challenges outlined in Section 1.1, this research aims to develop a systematic process for achieving Problem-Solution Fit (PSF) in deep-tech ventures. By aligning technological innovations with validated problem areas, this approach seeks to bridge the gap between research-driven advancements and commercially viable solutions. The study addresses both theoretical and practical dimensions, offering actionable insights into the PSF challenge.

The overarching research question guiding this study is:
How can deep-tech ventures solve the "solution looking for a problem dilemma"?

This question frames the dual focus of the research: exploring theoretical strategies and practical tools to address the complexities of achieving PSF. To answer this comprehensively, the study is structured around four interconnected sub-questions:

SQ1: Why do deep-tech ventures often struggle to identify relevant problem areas for achieving PSF, and what insights can literature provide on overcoming these challenges?
This question establishes the theoretical foundation of the research. It synthesises knowledge on deep-tech commercialisation and identifies gaps in existing methodologies, emphasising the need for a systematic approach to problem discovery and prioritisation.

SQ2: How can insights from a single case study in the supply chain sector inform the development of a process for identifying and prioritising high-impact problem areas in deep-tech ventures?
Building on the theoretical groundwork of SQ1, this question uses an in-depth case study to provide empirical insights. It focuses on understanding the challenges and opportunities faced by a representative deep-tech ventures, uncovering patterns and critical factors in defining and validating problem areas.

SQ3: What criteria should be applied to prioritise and validate problem areas, ensuring they are actionable, solvable, and aligned with market needs?
This question builds on the findings of SQ1 and SQ2 to develop criteria for evaluating problem areas systematically. It ensures that technological capabilities align with stakeholder needs, balancing feasibility with potential impact.

SQ4: What does a Problem-Solution Fit (PSF) process look like that supports deep-tech ventures in aligning their capabilities with validated problem areas?
Integrating theoretical insights, empirical findings, and evaluation criteria, this question focuses on designing a replicable PSF process. This process aims to help ventures navigate uncertainty and align their innovations with real-world needs effectively.

This thesis focuses on the challenges and opportunities of achieving PSF in complex, multi-stakeholder environments, with a particular focus on deep-tech ventures in the supply chain sector. While grounded in an extended single case study, the insights are designed to contribute to a broader understanding of the systemic barriers to deep-tech commercialisation. Key barriers, such as fragmented data and stakeholder dynamics, are analysed to inform actionable criteria and design a Problem-Solution Fit process.

Through a combination of theoretical exploration and empirical investigation, this study offers practical and academically rigorous contributions. It provides a replicable process to support deep-tech ventures in transitioning from research-driven innovation to sustainble commercialisation, enabling alignment between technological potential and market needs.

1.3 Docklab/NexTwin

A Case Study of Deep-Tech Commercialisation

Docklab and NexTwin
Docklab is a venture studio that operates by simultaneously managing multiple research-driven projects funded through targeted subsidies. One of its main initiatives is NexTwin, a digital twin technology designed to optimise supply chains by integrating advanced data modelling and simulation capabilities. NexTwin aims to enhance transparency and operational efficiency across complex supply chain networks.

Why This Case Represents Deep-Tech Challenges
Docklab serves as a representative example of the complexities inherent in deep-tech commercialisation. Unlike single-product start-ups, its multi-project approach introduces additional challenges, such as resource allocation, project prioritisation, and aligning different stakeholders with competing interests.

During the initial exploration of thesis topics, I observed that Docklab had a highly versatile and advanced technology in NexTwin. However, it lacked clarity on the specific problem areas where the technology could deliver measurable value. This disconnect exemplifies the broader “solution looking for a problem” dilemma faced by deep-tech ventures and inspired the central focus of this research.

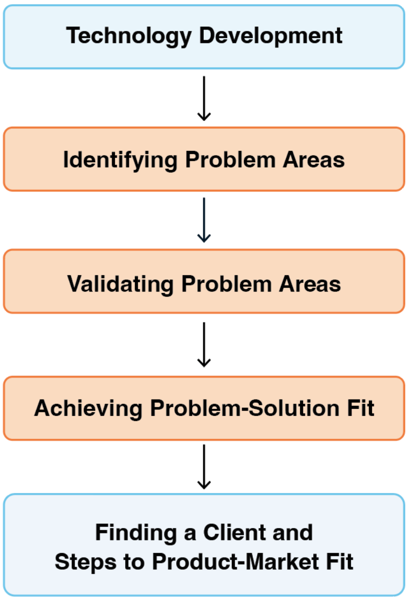
NexTwin highlights the need for a systematic approach to identifying and validating problem areas. Its versatility underscores the challenge of aligning technological capabilities with actionable market needs. This makes Docklab an ideal case study for exploring how deep-tech ventures can achieve Problem-Solution Fit (PSF) and transition from research-driven innovation to commercially viable solutions.

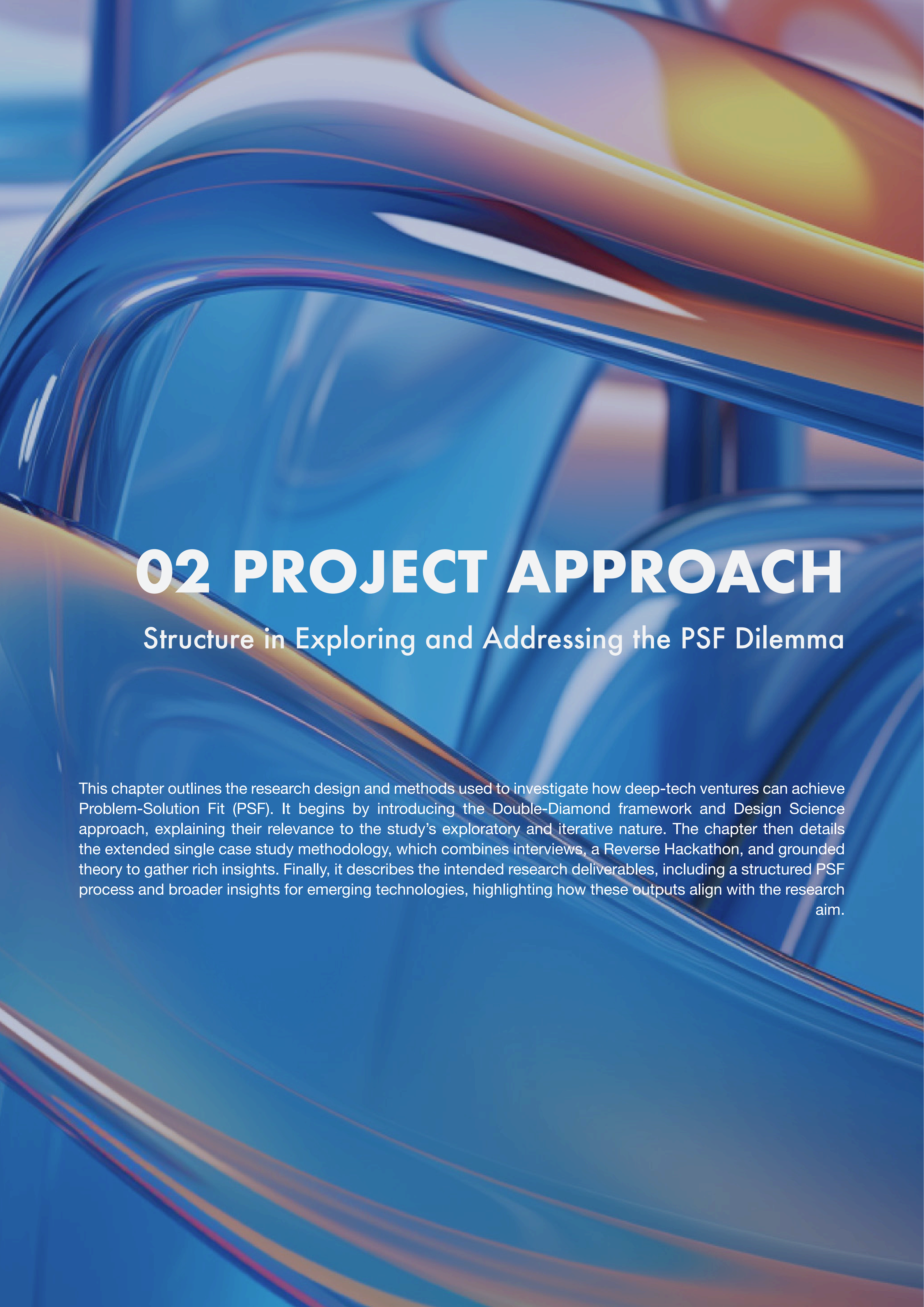
1.4 Concluding Chapter 1

This chapter introduced the challenges deep-tech ventures face in achieving Problem-Solution Fit (PSF), particularly when lacking predefined use cases or market segments. Existing frameworks, while valuable for later stages of commercialisation, fall short in guiding ventures through the early process of identifying and validating problem areas.

The research aims to address this gap by developing a structured PSF process to align technological capabilities with validated market needs. Guided by the research questions, the thesis combines theoretical exploration and empirical investigation to provide practical and academically grounded insights.

The next chapter, **Project Approach**, details the design science methodology and the extended single case study approach used to uncover and address these challenges.





02 PROJECT APPROACH

Structure in Exploring and Addressing the PSF Dilemma

This chapter outlines the research design and methods used to investigate how deep-tech ventures can achieve Problem-Solution Fit (PSF). It begins by introducing the Double-Diamond framework and Design Science approach, explaining their relevance to the study's exploratory and iterative nature. The chapter then details the extended single case study methodology, which combines interviews, a Reverse Hackathon, and grounded theory to gather rich insights. Finally, it describes the intended research deliverables, including a structured PSF process and broader insights for emerging technologies, highlighting how these outputs align with the research aim.

2.1 Research Design

The research design of this thesis aims to systematically explore how deep-tech ventures can achieve Problem-Solution Fit (PSF). To address this challenge, the study employs three complementary methodologies: the Double-Diamond framework, the Design Science approach, and an extended single case study. These methods ensure both theoretical rigour and practical relevance, enabling the development of a replicable process for aligning deep-tech innovations with market needs.

Double-Diamond Framework

The Double-Diamond framework *(British Design Council, 2005)* provides a guiding structure for this research rather than a rigid step-by-step model. This framework, which alternates between divergent and convergent thinking, helped navigate the iterative and exploratory nature of the “solution looking for a problem” dilemma in deep-tech ventures (see Figure 3). However, in practice, the process was less linear, with overlaps between phases and iterative refinement based on stakeholder feedback.

Each phase played a distinct role in shaping the Problem-Solution Fit (PSF) process:

- **Discover Phase**: This phase expanded the problem space by gathering insights through literature review, stakeholder interviews, and assumption mapping. The research explored multiple commercialisation frameworks (e.g. Lean Startup, Design Thinking) and identified key barriers for deep-tech adoption.
- **Define Phase**: The Reverse Hackathon played a central role in this phase, helping narrow down and validate the problem areas identified in the Discover phase. By engaging stakeholders in a co-creative problem-framing exercise, this method refined the assumptions and themes into concrete, industry-relevant problem areas. This phase resulted in the first structured iteration of the PSF process.
- **Develop Phase**: The PSF process was further refined, integrating stakeholder feedback. Additional validation helped adjust the criteria for prioritising problem areas, ensuring alignment with feasibility and industry needs.
- **Deliver Phase**: The final PSF process was structured into a replicable framework, incorporating practical applications for deep-tech ventures.

Design Science

The Design Science approach *(March & Smith, 1995; Hevner et al., 2004)* focuses on solving real-world problems by designing and evaluating practical artefacts. This aligns with the study’s aim of developing a systematic PSF process that is both actionable and relevant. *March & Smith (1995)* define Design Science as a cycle of building and evaluating artefacts, while *Romme & Dimov (2021)* emphasise its iterative and problem-driven nature, which fits with the Reverse Hackathon methodology used in this study.

Three key Design Science principles applied in this research (see Figure 4) are:

- **Problem Relevance**: Addressing the gap in existing commercialisation frameworks by focusing on ventures without predefined market segments.
- **Design as a Search Process**: Using iterative methods, such as the Reverse Hackathon and grounded theory, to refine the PSF process
- **Evaluation**: Assessing the PSF process against real-world challenges identified through the case study.

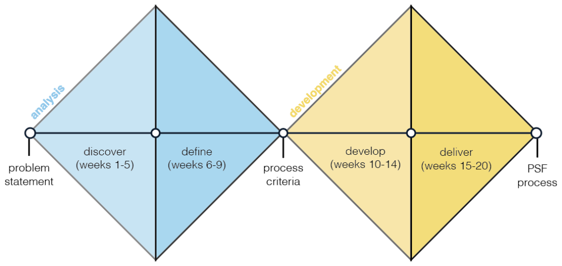


Figure 3. Adapted Double-Diamond Framework from British Design Council (2005)

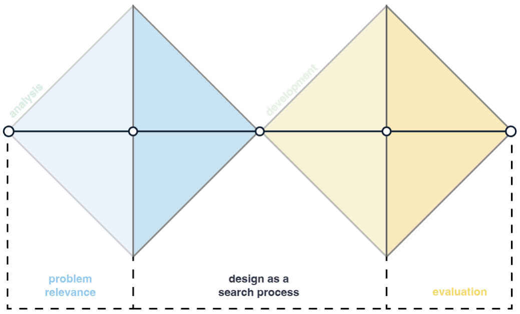


Figure 4. Overlay of Design Science Approach on Double-Diamond Framework

Extended Single Case Study with Multiple Methods

An extended single case study *(Yin, 2018)* was chosen to provide in-depth insights into the challenges faced by deep-tech ventures. Docklab, a venture studio exploring digital twin technology, served as the representative case. While specific to Docklab, the findings offer broader insights into the Problem-Solution Fit (PSF) process for similar ventures.

A multi-method approach was used to capture different dimensions of the problem:

- **Semi-Structured Interviews**: Explored stakeholder perspectives on market challenges (Figure 5).
- **Reverse Hackathon** *(Romme et al., 2023)*: Facilitated co-creation to refine and validate problem areas (Figure 6).
- **Grounded Theory** *(Glaser & Strauss, 1967; Charmaz, 2006)*: Used as an inductive data analysis method to identify patterns and refine the PSF process.

While Grounded Theory (GT) is often considered a methodology, this study applies it as a systematic analytical method, ensuring that insights from interviews and the Reverse Hackathon were iteratively coded and synthesised.

This multi-method approach ensures a comprehensive understanding of the complexities involved in aligning deep-tech innovations with market needs. Semi-structured interviews provided detail on different priorities and challenges at the individual level, while the Reverse Hackathon enabled co-creation to align these diverse perspectives with actionable problem areas. Grounded theory integrated these findings, ensuring a strong base for developing the PSF process.

By integrating these methods within the Double-Diamond framework and Design Science approach, the research achieved both depth and practical relevance. This structured methodology forms the foundation for addressing the PSF dilemma and achieving the research objectives.

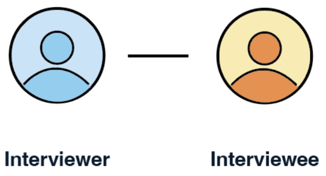


Figure 5. Interaction of Semi-Structured Interviews

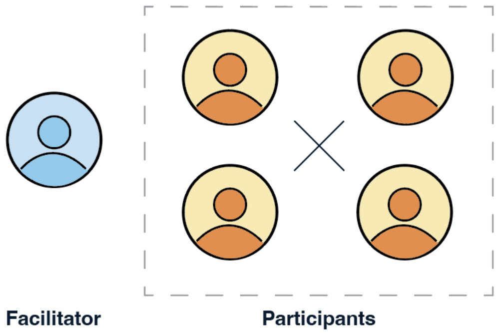


Figure 6. Interaction of Reverse Hackathon Session

2.2 Methods and Data Collection

The methods and data collection processes in this study were selected to align with the research aim of developing a structured process for achieving Problem-Solution Fit (PSF) in deep-tech ventures. By employing qualitative research techniques, the study explores stakeholder perspectives, identifies actionable problem areas, and generates insights into the challenges of early-stage commercialisation.

Overview of Methods (as illustrated in Figure 7)

1. Semi-Structured Interviews

Semi-structured interviews were conducted with stakeholders from the supply chain and energy sectors, including industry experts, potential end-users, and regulatory representatives. This method provided flexibility to explore specific areas of interest while enabling a deep understanding of stakeholder perspectives.

Purpose: To uncover critical barriers and opportunities in aligning technological capabilities with validated problem areas.
Contribution to Research Aim: The interviews provided rich, context-specific data, highlighting market dynamics, stakeholder needs, and challenges unique to deep-tech commercialisation.

2. Reverse Hackathon

The Reverse Hackathon served as a collaborative method for problem discovery and validation. Unlike traditional hackathons, this approach focused on engaging stakeholders to co-create and refine actionable problem areas for deep-tech ventures.

Purpose: To validate real-world applications of emerging technologies and capture diverse stakeholder insights.
Contribution to Research Aim: The Reverse Hackathon facilitated early stakeholder alignment, grounding the PSF process in practical, actionable insights.

3. Grounded Theory

Grounded theory was used as the primary data analysis method to systematically derive insights from the interviews and Reverse Hackathon data. This method allowed themes and patterns to emerge directly from the data, ensuring findings were not influenced by preconceived frameworks.

Purpose: To identify relationships, patterns, and themes within the data.
Contribution to Research Aim: Grounded theory supported the development of evidence-based criteria and processes for achieving PSF, ensuring findings were deeply rooted in empirical data.

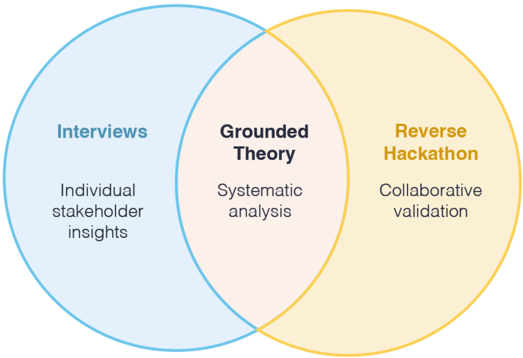


Figure 7. Venn-Diagram of Used Methods

Data Collection Process

The data collection process consisted of four distinct phases, ensuring a structured approach to gathering and analysing data:

1. Planning Phase:
- Developed interview guides tailored to explore stakeholder perspectives.
- Designed Reverse Hackathon protocols to align with research objectives, focusing on collaborative problem discovery and prioritisation.

2. Execution Phase:
- Conducted 11 semi-structured interviews across diverse stakeholders.
- Organised and facilitated a Reverse Hackathon involving key industry participants, focusing on co-creating and validating actionable problem areas.

3. Data Documentation:
- Recorded and transcribed all interviews and Reverse Hackathon sessions.
- Ensured comprehensive documentation for accurate analysis.

4. Analysis Phase: Applied grounded theory to iteratively code, categorise, and synthesise data into actionable themes and insights.

Alignment with Research Aim

This multi-method approach ensures a holistic exploration of the challenges faced by deep-tech ventures. The combination of stakeholder engagement (through interviews and the Reverse Hackathon) and rigorous data analysis (via grounded theory) enabled the study to:

- Identify and prioritise **high-impact problem areas**
- Develop a **replicable process** for achieving PSF
- Bridge **theoretical** insights with **practical** applications

By integrating diverse stakeholder perspectives with systematic data analysis, the study addresses the complexities of transitioning ventures from “solutions looking for a problem” to market-aligned innovations.

2.3 Research Deliverables

Building on the study’s findings, this research delivers a structured Problem-Solution Fit (PSF) process that enables deep-tech ventures to systematically identify, prioritise, and validate problem areas. This process provides a replicable framework that:

- **Guides problem discovery** by structuring how ventures uncover actionable opportunities aligned with their technological capabilities.
- **Suppots validation** by establishing clear criteria to assess feasibility, significance, and market alignment.
- **Facilitates decision-making** by providing structured steps to determine whether to pivot, pause, or proceed.

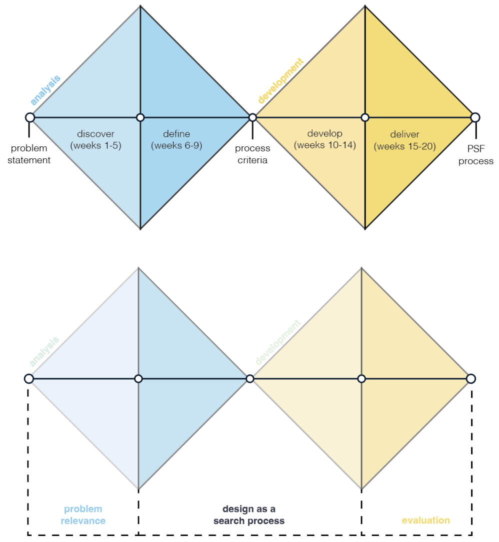
Beyond the PSF process, the research offers **stakeholder-driven insights** into deep-tech commercialisation challenges, particularly in **multi-stakeholder environments**. These insights contribute to bridging the gap between tech-push innovation and market-driven adoption.

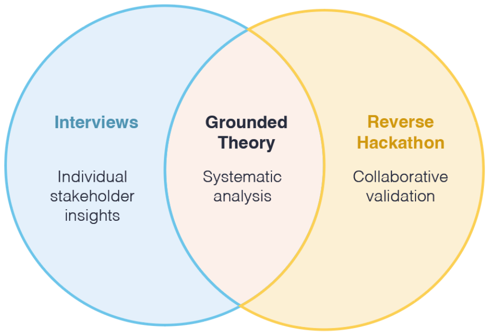
Additionally, this study applies and extends the Reverse Hackathon as a co-creative methodology for problem validation in ambiguous contexts, demonstrating its effectiveness in aligning deep-tech innovations with concrete industry needs.

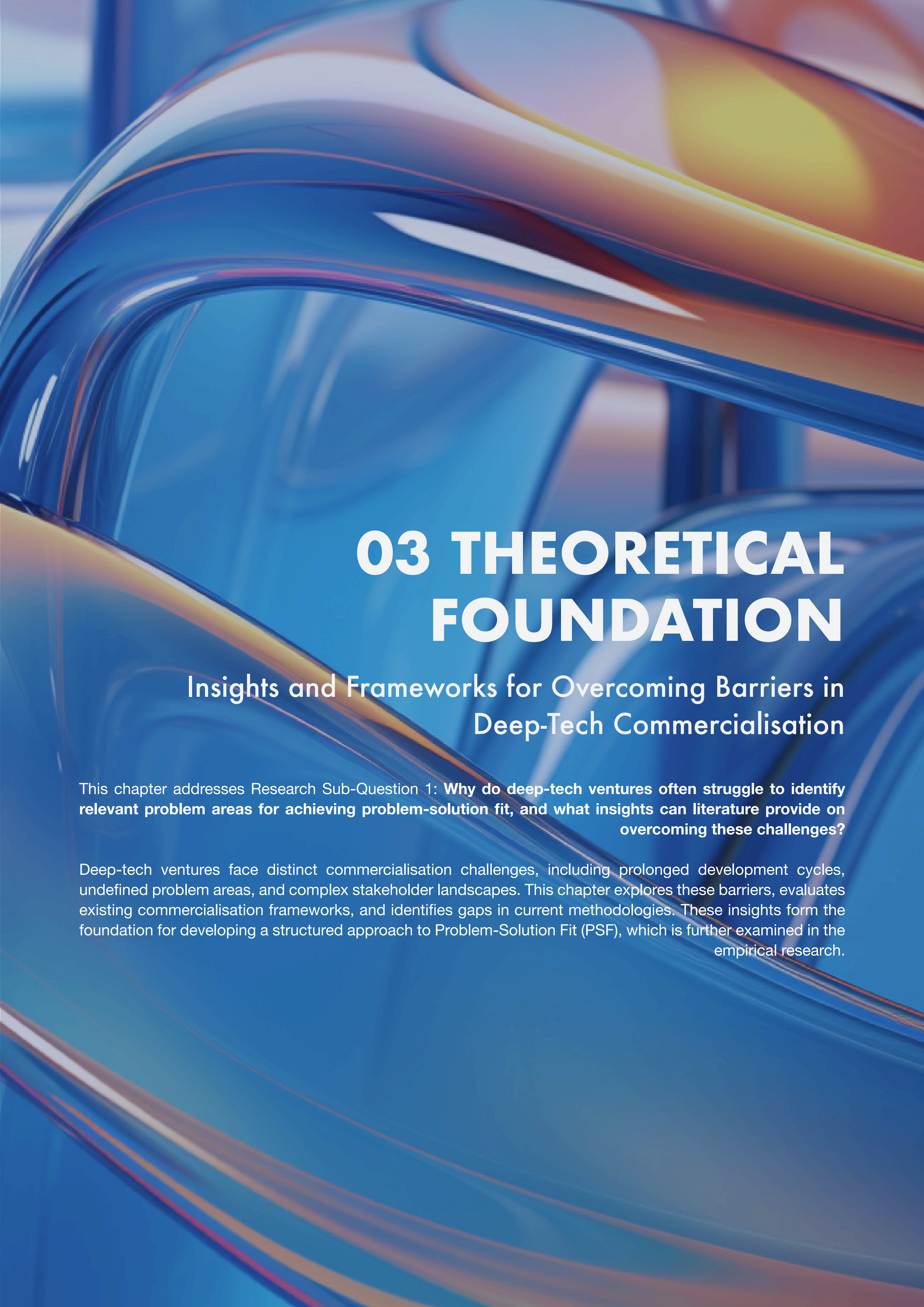
Through these deliverables, this thesis provides practical tools and structured approaches to help deep-tech ventures transition from “solutions looking for a problem” to market-aligned innovations.

2.4 Concluding Chapter 2

This chapter outlines the research design and methodology underlining the study. By leveraging the Double Diamond framework and a Design Science approach, the research systematically explores the challenges of achieving Problem-Solution Fit (PSF) for emerging technologies. Grounded in an extensive single case study, the study employs qualitative methods, including interviews and a Reverse Hackathon, with grounded theory guiding data analysis. These methods are tailored to uncover actionable insights, prioritise problem areas, and validate the proposed PSF process. The research deliverables, including a structured PSF process and broader insights for deep-tech ventures, aim to bridge the gap between technological innovation and market readiness. This foundation sets the stage for a detailed exploration of theoretical frameworks in the next chapter.







03 THEORETICAL FOUNDATION

Insights and Frameworks for Overcoming Barriers in Deep-Tech Commercialisation

This chapter addresses Research Sub-Question 1: **Why do deep-tech ventures often struggle to identify relevant problem areas for achieving problem-solution fit, and what insights can literature provide on overcoming these challenges?**

Deep-tech ventures face distinct commercialisation challenges, including prolonged development cycles, undefined problem areas, and complex stakeholder landscapes. This chapter explores these barriers, evaluates existing commercialisation frameworks, and identifies gaps in current methodologies. These insights form the foundation for developing a structured approach to Problem-Solution Fit (PSF), which is further examined in the empirical research.

3.1 The Concept of Problem-Solution Fit

The "Solution Looking for a Problem" Dilemma

Emerging technologies such as digital twins, artificial intelligence, and blockchain hold broad applicability across industries but often struggle to find immediate adoption. These technologies, classified as General Purpose Technologies (GPTs) *(Jovanovic & Rousseau, 2005)*, offer transformative potential but lack predefined use cases. As a result, many deep-tech ventures struggle to position their innovations within existing market structured, leading to what is commonly referred to as the "**solution looking for a problem**" dilemma *(Leiva & Kuschel, 2020)*. Unlike start-ups that develop products in response to clearly defined market needs, deep-tech ventures often emerge from technological advancements rather than market demand. This disconnect makes it difficult to establish commercial viability.

Without a structured approach to identifying problem areas, deep-tech ventures risk investing resources into applications that fail to gain traction. This often results in prolonged experimentation, misalignment with industry needs, and difficulty in securing stakeholder buy-in (*Haessler et al., 2022*). While existing market validation frameworks offer guidance on refining solutions based on user needs, they are typically designed for contexts where demand is **already visible**. In contrast, deep-tech ventures must first determine **where** their technology provides the most value before traditional validation processes can take effect.

Defining Problem Areas in Deep-Tech Ventures

In this thesis, problem areas are defined as unmet needs, inefficiencies, or industry challenges where a technology can deliver measurable value *(Blank, 2013)*. Identifying these areas is critical for achieving Problem-Solution Fit (PSF): de process of aligning technological capabilities with industry-relevant challenges.

However, this process is particularly complex for deep-tech ventures because **market demand is often ambiguous, fragmented, or emerging rather than well-defined.**

The difficulty of defining problem areas in deep-tech is shaped by multiple interrelated factors, including unclear demand signals, multi-stakeholder environments, and integration barriers. These challenges, further explored in Section 3.2, underscore the limitations of traditional market validation approaches in deep-tech settings. Unlike consumer-driven markets, where start-ups can rely on iterative customer feedback, deep-tech innovations frequently require a more proactive and structured approach to problem discovery.

Limitations of Existing Frameworks in Deep-Tech Commercialisation

Achieving Problem-Solution Fit (PSF); the process of identifying, validating, and aligning technological capabilities with clearly defined, solvable market problems, is a critical challenge in deep-tech ventures. Several established methodologies attempt to bridge the gap between innovation and market adoption, but they fall short in deep-tech contexts:

- **Lean Startup** (*Ries, 2011*): Designed for iterative product development based on rapid user feedback, this framework assumes a clearly defined customer base. In deep-tech, however, potential useres may be unaware of the technology's relevance, making rapid iteration ineffective in the early stages.

- **Jobs to be Done”** (*Christensen, 2007*): A customer-needs framework that examines why useres adopt certain solutions to complete tasks. While useful in established markets, it assumes that customers already perceive a problem as solvable. Deep-tech ventures often face the challenge that industries have not yet articulated these unmet needs in ways that align with emerging technologies.
- **Customer Development Model** (*Blank, 2013*) : highlights continuous stakeholder engagement but presumes a baseline understanding of the market. Deep-tech ventures often lack this foundation, requiring structured methods to first uncover and validate problem areas before engaging customers effectively.

While these frameworks provide effective tools for solution refinement and market entry, they do not sufficiently address the earlier challenge of defining and validating problem areas in deep-tech commercialisation. They assume a level of market awareness and demand that deep-tech ventures do not have from the outset.
This gap suggests that achieving Problem-Solution Fit (PSF) requires additional structuring beyond conventional start-up methodologies.

Positioning Problem-Solution Fit Within Deep-Tech Commercialisation
The challenge of achieving Problem-Solution Fit (PSF) reflects a broader gap in the commercialisation of deep-tech ventures. Unlike start-ups that refine existing product-market relationships, deep-tech must first establish these relationships from scratch. However, existing literature does not provide a dedicated PSF framework, leaving several questions unanswered:

- How can deep-tech ventures systematically explore problem areas when demand signals are weak or indirect?
- What methodologies are most effective for defining and validating problem areas in multi-stakeholder environments?
- How can problem areas be validated before significant development efforts are committed?

These questions remain unresolved in existing literature, underscoring the need for further investigation. The following sections expand on this discussion by examining barriers to deep-tech commercialisation and the applicability of existing frameworks. Together, these insights provide the groundwork for evaluating new approaches to early-stage problem discovery and validation in deep-tech settings.

3.2 Barriers to Deep-Tech Success

The commercialisation of deep-tech ventures presents distinct challenges that stem from the complexity of these technologies and their undefined market applications. Deep-tech ventures are often driven by technological advancements that lack clear pathways to adoption. This disconnect creates barriers in three key areas: stakeholder engagement, integration with existing systems, and the tension between market-pull and tech-push approaches. Each of these factors contributes to the difficulty of achieving Problem-Solution Fit (PSF) and, ultimately, commercial viability.

3.2.1 The Role of Stakeholder Collaboration

Stakeholder collaboration is essential for aligning deep-tech innovations with marketneeds, yet it is often insufficient or fragmented. Unlike conventional industries where customer feedback can be easily gathered, deep-tech ventures must navigate multi-stakeholder environments, including regulatory bodies, industry partners, and end-users, each with distinct priorities and constraints (*Liu et al., 2018).* Misalignment among these groups delays market entry and hinders validation of problem areas *(Lehtinen & Aaltonen, 2020)*.

Granovetter's (1985) concept of "embeddedness" highlights that stakeholder engagement is not purely a procedural issue but also a social challenge, relying on trust and relational dynamics. Without strong stakeholder trust, ventures risk resistance to innovation, misaligned priorities, and uncertainty in scaling their solutions.

Why Stakeholder Engagement Often Falls Short
Many deep-tech ventures struggle to engage stakeholders early, resulting in tech-driven solutions developed in isolation. This lack of engagement contributes to product-market misalignment, slowing adoption and reducing commercial potential *(Palo-Oja et al., 2015)*.

Iterative frameworks like Lean Startup rely on direct customer feedback, but these methods are less effective for deep-tech ventures, which often lack clearly defined users *(De Cock et al., 2019)*. Without structured collaboration, ventures may also overlook key constraints such as scalability, regulatory compliance, or industry-specific adoption barriers.

Structured Approaches to Improve Engagement
Structured methodologies, such as Reverse Hackathons *(Romme et al., 2023)*, offer practical tools for improving stakeholder collaboration. These approaches facilitate co-creation and iterative problem refinement, enabling ventures to incorporate diverse perspectives, including customer needs, regulatory constraints, and operational requirements, into their innovation process.

As *De la Tour et al. (2017)* argue, collaboration between start-ups and corporates is particularly critical in deep-tech contexts, where scaling often requires shared infrastructure, trust-building, and alignment on strategic goals.

Implications for Stakeholder Engagement
A structured approach to stakeholder engagement can accelerate deep-tech commercialisation by reducing misalignment and enhancing market fit. By leveraging customer-centric methodologies, such as Jobs to be Done *(Christensen, 2007)*, ventures can refine their solutions based on real-world industry needs rather than hypothetical applications.

Without proactive stakeholder involvement, ventures face longer development cycles, ragulatory roadblocks, and misaligned value propositions. Effective engagement strategies, therefore, serve as a **critical enabler of commercial success** in deep-tech ventures *(Bobelyn et al., 2023)*.

3.2.2 Integration Challenges

Many deep-tech technologies, particularly digital twins, AI-driven analytics, and blockchain solutions, rely on seamless interoperability with existing infrastructure. However, deep-tech ventures frequently face integration barriers due to fragmented data sources, non-standardised systems, and high adoption costs.

McIntyre (2014) highlights that the absence of standardisation across industries increases integration costs and reduces the feasibility of adopting emerging solutions. Furthermore, *Lai (2017)* and *Davis (1989)* argue that perceived complexity and unclear value propositions make organisations resistant to adopting new technologies, as they often prioritise stability over innovation.

Why Integration Barriers Persist
Deep-tech ventures frequently experience operational misalignment due to:

- Fragmented data ecosystems that prevent seamless interoperability *(Wittenburg & Strawn, 2021)*.
- Inconsistent data-sharing practices across industries, leading to inefficiencies.
- Lack of industry-wide standardisation, increasing the cost and complexity of technology adoption.

For technologies like digital twins, which rely on gathering and interpreting data from multiple sources, poor integration standards severely limit scalability and impact.
Kitchin (2014) suggests that advancements in data science methods, such as data harmonisation and AI-driven analytics, can partially mitigate these barriers by improving the ability of organisations to extract actionable insights from fragmented datasets.

Potential Solutions: Standardisation and Collaboration
To reduce integration barriers, ventures must prioritise industry-wide data protocols and collaborative standardisation efforts. *Besen & Farrell (1994)* note that while private data formats can provide short-term competitive advantages, shared standards enable broader interoperability and scalability.

For deep-tech ventures, partnerships with market leaders and participation in standard-setting initiatives can reduce adoption resistance and enhance trust in emerging technologies.

Implications for Deep-Tech Ventures
Failure to address integration challenges leads to prolonged commercialisation timelines, limited scalability, and reduced stakeholder confidence. Conversely, ventures that align with existing standards, or contribute to shaping new ones, can accelerate adoption and enable broader ecosystem collaboration.

3.2.3 Strategic Tensions

Deep-tech ventures must navigate the tension between market-pull (demand-driven) and tech-push (innovation-driven) strategies. While market-pull focuses on solving existing problems, tech-push prioritises leveraging new capabilities to create demand. The challenge lies in balancing these approaches to ensure innovations align with industry needs.

Challenges of Market-Pull and Tech-Push Dynamics
Market-pull strategies are often ineffective in deep-tech because potential applicatoions are fragmented or not yet recognised. Conversely, tech-push strategies risk producing solutions with no immediate relevance to industry challenges *(Walsh et al., 2002)*. Striking a balance between the two is critical yet underexplored in existing literature.

A Hybrid Approach for Strategic Balance
Blending market-pull and tech-push strategies can help deep-tech ventures validate problem areas while demonstrating value (*Gans & Stern (2002).* By integrating regulatory insights, industry collaboration, and iterative problem validation, ventures can improve alignment with market needs.

Pynnönen et al. (2019) suggest that early partnerships with regulatory bodies and industry experts can accelerate the identification of high-impact problem areas and enhance venture credibility.

Implications for Commercialisation Strategy
Deep-tech ventures must adopt adaptive commercialisation strategies that incorporate elements of both market-pull and tech-push. Flexible leadership and structured validation mechanisms, such as Reverse Hackathons, can help ventures ensure that innovations are tested against real industry challenges before scaling.

Conclusion: Addressing Core Commercialisation Challenges
Deep-tech ventures encounter three interrelated barriers in early-stage commercialisation, as illustrated in Figure 8:
1. Stakeholder Engagement: Multi-stakeholder environments create misalignment due to conflicting priorities, trust issues, and fragmented data ecosystems.
2. Integration Challenges: Adoption is slowed by legacy systems, interoperability issues, and high implementation costs.
3. Market-Pull vs. Tech-Push Tension: Ventures struggle to balance leveraging advanced capabilities (tech-push) with addressing clear industry needs (market-pull).

These factors do not operate in isolation; their overlaps present unique commercialisation challenges that require structured collaboration, standardisation, and iterative problem discovery.
While existing frameworks offer partial solutions, they do not fully account for these deep-tech-specific barriers, particularly in the early stages of problem discovery. The next section evaluates these frameworks, identifying gaps and the need for a tailored approach to deep-tech commercialisation.

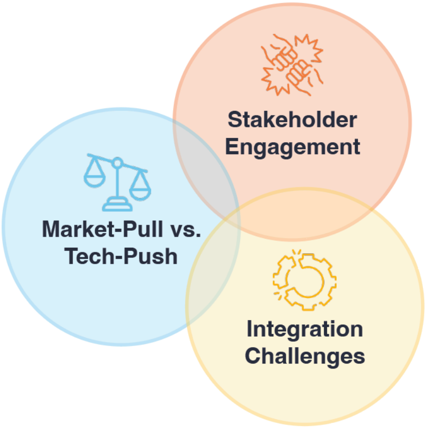


Figure 8. Interconnected Deep-Tech Commercialisation Challenges

3.3 Adapting Methods for Deep-Tech Commercialisation

A range of commercialisation methods, including Lean Startup *(Ries, 2011)*, Design Thinking *(Kelly & Littman, 2001)*, and Stage-Gate *(Cooper, 1990),* provide structured ways to develop and refine innovations. These methods are widely used in entrepreneurship, corporate R&D, and new product development, making them relevant for assessing how deep-tech ventures might structure their commercialisation process.

However, deep-tech ventures face distinct challenges that differ from traditional product-market fit approaches. Market demand is often unclear, stakeholders are fragmented, and adoption depends on regulatory approval and ecosystem shifts rather than individual purchasing decisions. Additionally, technical feasibility and integration barriers play a greater role, making rapid iteration and short-term validation less effective.

This section evaluates widely used commercialisation methods, highlighting their strengths and limitations in deep-tech contexts. While each method provides useful mechanisms, none fully address the Problem-Solution Fit (PSF) challenge in deep-tech, justifying the need for an alternative approach.

Lean Startup *(Ries, 2011)* focuses on rapid prototyping and MVP-driven feedback. It assumes that customer needs are either already known or easily discoverable, making it effective for refining solutions in fast-paced markets.

Deep-tech innovations often lack clearly defined user segments and require longer development timelines, making MVP-based iteration impractical. Short-term experimentation overlooks systemic adoption barriers common in highly regulated or complex industries *(Hines et al., 2018)*.

Design Thinking *(Kelly & Littman, 2001)* is a creative problem-solving method that focuses on empathy, ideation, and iterative prototyping to uncover latent needs. While valuable for aligning solutions with customer pain points, it assumes that commercialisation is primarily driven by end-user preferences.

Deep-tech adoption is rarely decided by a single end-user, but rather by multi-stakeholder ecosystems requiring regulatory alignment and industry-wide adoption. Additionally, the method is resource-intensive, making it difficult to apply in industries where technical feasibility and infrastructured constraints outweigh individual user needs *(Mueller & Thoring, 2012)*.

The **Stage-Gate** model *(Cooper, 1990)* is a project management method used to manage risk and resource allocation through defined decision points. It works well for scaling established products *(O'Connor, 1994)* but its rigid structure does not align with the uncertainty and iteration required in early-stage deep-tech commercialisation. Emerging problem areas often evolve, requiring flexibility rather than fixed decision gates.

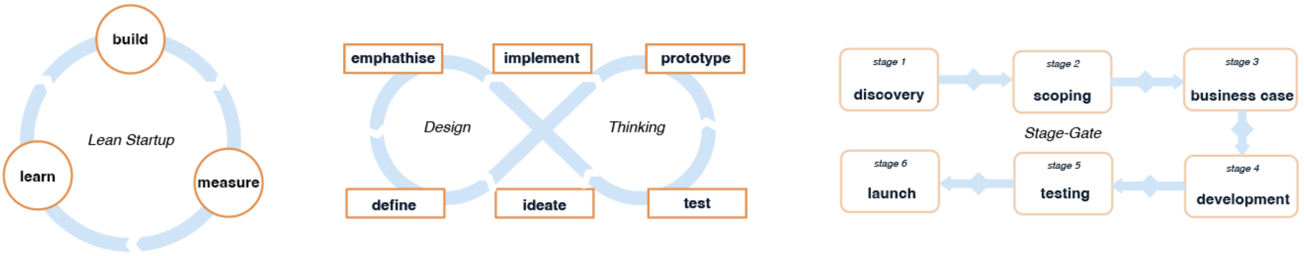


Figure 9. Visualisation of Three Widely Used Methods (from left to right: Lean Startup, Design Thinking, Stage-Gate). Adapted from Ries (2011), Kelly & Littman (2001), and Cooper (1990).

Although **Market Search Alliances (MSAs)** *(Bruneel et al. (2020)* are not a formalised method, they describe a collaborative approach where start-ups work with industry partners to refine problem areas. However, MSAs lack a structured methodology, making their application inconsistent, and their reliance on existing networks can exclude ventures without strong industry ties.

Why Existing Methods Fall Short for Deep-Tech

While these methods help refine solutions, they do not fully address the three key deep-tech barriers identified in Chapter 2:

- Stakeholder Engagement: Existing methods rarely integrate early-stage multi-stakeholder alignment, which is essential for deep-tech adoption.
- Market-Pull vs. Tech-Push: None provide structured problem discovery before market validation, making them unsuitable for deep-tech ventures still defining their use cases.
- Integration Challenges: Conventional methods do not address technical feasibility, regulatory barriers, and ecosystem constraints that influence deep-tech adoption.

Since no single method sufficiently incorporates all three elements, as illustrated in Table 1, this research introduces the Reverse Hackathon as an alternative deep-tech problem discovery method.

The Reverse Hackathon: A Structured Approach to Deep-Tech Problem Discovery

Unlike the previously discussed methods, the **Reverse Hackathon** (*Romme et al., 2023),* shifts the focus from passive market validation to active problem discovery. It provides a structured method designed for engaging stakeholders, refining problem areas, and reducing commercial uncertainty.

Why it fits deep-tech needs:

- Engages stakeholders early, ensuring alignment with industry needs
- Facilitates cross-disciplinary collaboration, integrating different stakeholder perspectives
- Structured problem validation, reducing ambiguity and increasing the likelihood of commercial relevance

By addressing deep-tech-specific gaps, the Reverse Hackathon serves as a necessary complement to existing methods, ensuring ventures can transition from “solution looking for a problem” to validated, industry-relevant problem areas before investing in commercialisation. However, its success depends on skilled facilitation, ensuring discussions remain focused and lead to concrete outcomes, and stakeholder alignment on priorities.

Method	Strengths	Limitations	Alignment with Challenges
Lean Startup (Ries, 2011)	Rapid iteration, MVP testing	Assumes known user needs, short-term focus	✓ Market-Pull vs. Tech-Push (partially) ✗ Weak on Stakeholder Engagement ✗ Weak on Integration Challenges
Design Thinking (Kelly & Littman, 2001)	Stakeholder engagement, user-driven innovation	Resource-intensive, lacks industry-wide adoption mechanisms	✓ Stakeholder Engagement (partially) ✗ Weak on Market-Pull vs. Tech-Push ✗ Weak on Integration Challenges
Stage-Gate (Cooper, 1990)	Risk management, structured resource allocation	Rigid structure, assumes predictable market conditions	✓ Integration Challenges(partially) ✗ Weak on Stakeholder Engagement ✗ Weak on Tech-Push vs. Market-Pull
Market Search Alliances (Bruneel et al., 2020)	Industry partnerships for problem validation	Lacks structure, relies on existing networks	✓ Stakeholder Engagement (partially) ✗ Weak on Market-Pull vs. Tech-Push ✗ Weak on Integration Challenges

Table 1. Strengths, Limitations, and Deep-Tech Fit of Methods

3.4 Concluding Chapter 3

This chapter established the theoretical foundation for addressing deep-tech commercialisation challenges, with a focus on achieving Problem-Solution Fit (PSF). Three key barriers; stakeholder engagement, integration challenges, and the tension between market-pull and tech-push strategies, were explored in depth, highlighting why deep-tech ventures struggle to align their technologies with validated market needs.

A critical evaluation of frameworks revealed significant limitations in their applicability to deep-tech settings. Approaches such as Lean Startup, Design Thinking, and Stage-Gate were found to be less effective due to their reliance on pre-existing market clarity, rigid evaluation structures, or high resource demands. Market Search Alliances (MSAs) provide valuable insights into collaborative engagement but lack a systematic problem-definition process.

Against this backdrop, the Reverse Hackathon emerged as a promising methodology for early-stage problem validation in deep-tech ventures. Unlike widely used frameworks, it facilitates structured stakeholder engagement, iterative problem refinement, and cross-disciplinary collaboration, making is particularly suited to environments where market needs are uncertain or fragmented.

These insights (see Figure 10) set the stage for the next chapter, which presents the qualitative research conducted to test and refine the Reverse Hackathon framework. This research combines stakeholder interviews and an applied case study to evaluate its effectiveness in aligning deep-tech innovations with validated market needs.

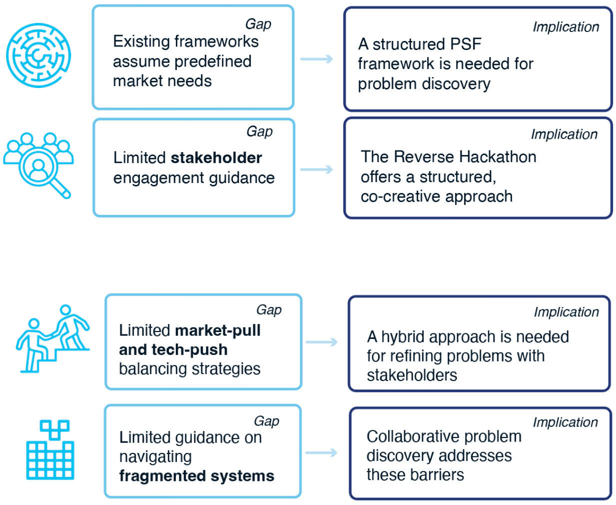


Figure 10. Summarised Literature Gaps and Thesis Implications

04 QUALITATIVE RESEARCH

Exploring Stakeholder Perspectives

This chapter addresses Research Sub-Question 2: **How can insights from a single case study in the supply chain sector inform the development of a process for identifying and prioritising high-impact problem areas in deep-tech ventures?**

Using Docklab as a case study, this research combines semi-structured interviews and a Reverse Hackathon to extract actionable insights and validate stakeholder-aligned problem areas. These methods help refine a structured approach to Problem-Solution Fit (PSF) by identifying real-world challenges and market needs.This chapter outlines the research design, data collection methods, and analytical approach, providing the foundation for developing practical strategies.

4.1 Methods for Exploring Stakeholder Insights

This section describes the qualitative methods used to investigate how deep-tech ventures can achieve Problem-Solution Fit (PSF). Two complementary methods were employed: semi-structured interviews to capture individual stakeholder perspectives, and a Reverse Hackathon to validate and refine problem areas through collaborative engagement.

Both methods were tailored to undefined markets and multi-stakeholder environments, ensuring that insights contributed directly to the development of a structured PSF process.

4.1.1 Semi-Structured Interviews

Purpose and Design

Semi-structured interviews were conducted to explore market challenges, adoption barriers, and opportunities for digital twin technology. This method followed best practices from *Goffin et al. (2019)*, ensuring rigour through triangulation of data sources for reliability, transparency in documentation, and systematic coding techniques for structured analysis. Following *Griffin & Hauser's (1993)* guidelines, interview questions were adapted to each participant's expertise and industry context. This allowed for a nuanced exploration of themes such as regulatory challenges, sustainability goals, and digital twin adoption barriers.

Process

The interview guide (see Appendix B) included open-ended questions, focusing on:

- The role of digital twins in supply chains and energy sectors
- Adoption challenges, including ESG and regulatory compliance
- Potential impact on efficiency, risk management, and collaboration
- Barriers such as data integration and stakeholder misalignment

Execution

- Participants provided informed consent, and interviews were recorded for accuracy.
- Sessions were conducted online or in person, lasting 30 to 55 minutes.
- Transcripts were generated using Riverside.fm, then manually reviewed for accuracy.

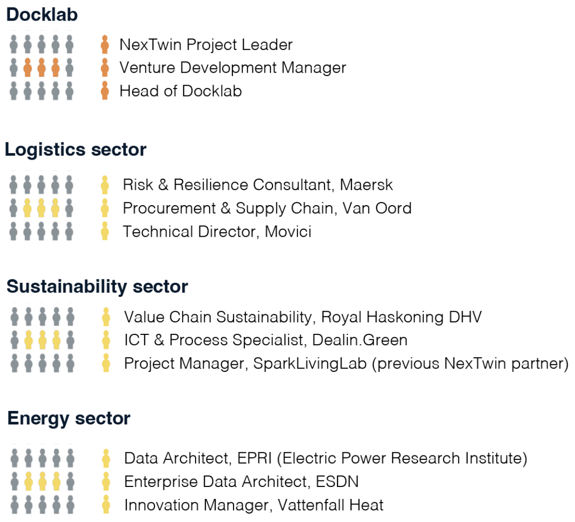
Sample

A purposive sampling strategy targeted diverse stakeholders from the supply chain and energy sectors. Participants, also detailed in Figure 11, included:

- **Internal Stakeholders** (Docklab team members) who provided insights into organisational challenges.
- **External Stakeholders** (industry experts, sustainability specialists, and innovation managers) who shared perspectives on market dynamics and technology adoption.

Contribution to Research Aim

These interviews provided rich qualitative data, validating assumptions about industry needs and informing the design of the Reverse Hackathon.



Docklab

- NexTwin Project Leader
- Venture Development Manager
- Head of Docklab

Logistics sector

- Risk & Resilience Consultant, Maersk
- Procurement & Supply Chain, Van Oord
- Technical Director, Movici

Sustainability sector

- Value Chain Sustainability, Royal Haskoning DHV
- ICT & Process Specialist, Dealin.Green
- Project Manager, SparkLivingLab (previous NexTwin partner)

Energy sector

- Data Architect, EPRI (Electric Power Research Institute)
- Enterprise Data Architect, ESDN
- Innovation Manager, Vattenfall Heat

Figure 11. Interview Sampling

4.1.2 Reverse Hackathon

Purpose and Design

Building on the interview findings, the Reverse Hackathon was designed to synthesise and validate problem areas through collaborative engagement,. The session encouraged co-creation, allowing stakeholders to refine market-relevant challenges and explore commercialisation strategies for deep-tech. This method was structured using *Romme's (2023)* HighTechXL framework, aligning with best practices in deep-tech innovation. The session focused on identifying actionable problem areas, refining market adoption strategies, and prioritising opportunities. The total session lasted three hours, ensuring sufficient time for a 5-minute individual brainstorm, and a 20-25 minute group discussion, analysis, and structured decision-making.

Process and Structure

The Reverse Hackathon was organised into four main activities, as illustrated in Figure 12:

- **Obstacle Analysis**: Participants built on key barriers from interviews, categorising them into regulatory, financial, and operational constraints.
- **Ideal Market Identification**: Explored potential beachhead markets for digital twin applications, focusing on compliance, efficiency, and scalability.
- **Role-Reversal Exercise**: Participants adopted different stakeholder perspectives (e.g. investment decision-makers, sustainability managers), to evaluate adoption challenges.
- **Prioritisation**: Ranked market opportunities based on impact, feasibility, and industry alignment.

Ensuring Data Accuracy

- The session was recorded (with informed consent) and transcribed using Riverside.fm for accuracy.
- Supplementary materials (photos of sticky notes, whiteboard outputs, and posters) were collected to document discussions.
- The researchers ensured equal participation by guiding discussions and using structured prompts to reduce bias.

Sample

A purposive sampling strategy was used to ensure diverse perspectives. Participants included the researcher (facilitator), two Docklab team members (Project Leader and Venture Development Manager), and five external industry experts from the supply chain, sustainability, and energy sectors. Industry professionals had not participated in prior interviews, ensuring fresh perspectives on market adoption challenges. To maintain balanced discussions, participants included both technical decision-makers (e.g. supply chain managers) and strategic leaders (e.g. business development managers).

Contribution to Research Aim

The Reverse Hackathon expanded the interview findings, demonstrating the value of structured stakeholder engagement in defining problem areas. By shifting the discovery process from passive observation to active co-creation, this method provided critical empirical data to shape a Problem-Solution Fit (PSF) process tailored for deep-tech ventures. Additionally, the structured prioritisation helped refine high-impact market opportunities, offering a replicable methodology for similar deep-tech commercialisation challenges.

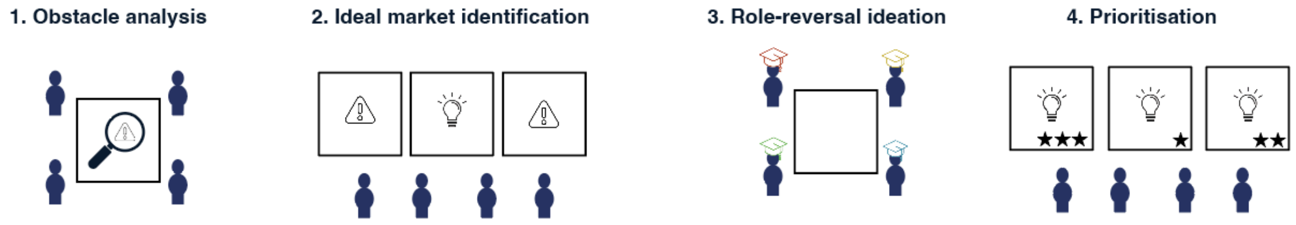


Figure 12. Reverse Hackathon Session Structure

4.2 Data Analysis Approach

This section describes the grounded theory approach used to analyse qualitative data collected from semi-structured interviews and the Reverse Hackathon. Grounded theory was chosen for its iterative and flexible methodology, allowing patterns and themes to emerge naturally from the data (*Charmaz, 2006; Glaser & Strauss, 1967*). This approach ensured that insights remained closely aligned with stakeholder perspectives and the contextual realities of deep-tech commercialisation challenges.

Coding Process

The data analysis process was structured into three stages: initial coding, focused coding, and categorisation (see Figure 13).

1. Initial Coding: Capturing Detailed Insights

Process: Transcripts from interviews and the Reverse Hackathon were reviewed line-by-line. Descriptive codes were assigned to phrases or sentences that represented key ideas. In vivo coding (*Birks & Mills, 2015*) was used to retain the authenticity of participant voices. For example:

Code: “Resistance to change as a major adoption challenge”

Quote: *“Like when you bring about a change in the way of working, there’s always resistance faced. That’s the biggest challenge.”*

Outcome: This stage generated approximately 1,075 initial codes from the interviews, reflecting a wide array of insights from operational challenges to strategic opportunities. After the interviews were coded, the Reverse Hackathon was conducted, yielding an additional 69 initial codes.
These hackathon-derived codes were unique from the interview findings and tended to be more actionable, reflecting the collaborative problem-solving nature of the session.

2. Focused Coding: Identifying Patterns and Relationships

Process: Codes were grouped based on recurring ideas, relationships, or overlapping concepts. This phase aimed to condense the broad range of initial codes into more structured themes. Redundant or overlapping codes were merged into broader thematic groups to improve clarity. For instance:

Merged Codes: “Data fragmentation” and “Interoperability challenges” were unified under the theme “Integration barriers”.

Outcome: This phase resulted in 15 intermediate themes, reflecting broad industry challenges. However, **contradictions surfaced** within some themes. For example, in “Customer engagement strategies”, some stakeholders reported effective collaboration, while others highlighted communication gaps. These contradictions required further refinement in the next phase.

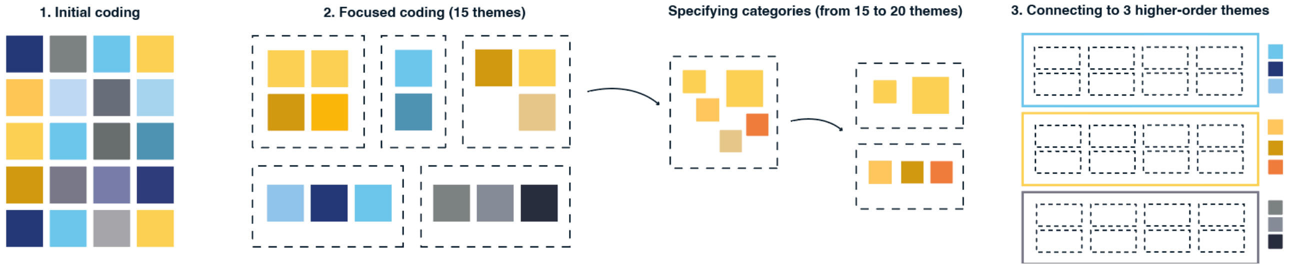


Figure 13. Coding Process

3. Categorisation: Establishing Higher-Order Themes

Process: The 15 intermediate themes were further refined to address internal contradictions and capture nuanced challenges. This led to the expansion from 15 to **20 more specific categories**, ensuring that stakeholder complexities and market-specific barriers were properly represented. The final 20 categories were grouped into three overarching themes to structured the findings: **(1) Market Challenges, (2) Organisational Challenges, and (3) Industry Dynamics**.

Example of Theme Refinement: The broad category “Market & adoption barriers” was split into distinct categories such as “Legacy Systems” and “Investment Hesitation” to capture specific adoption bottlenecks.

Outcome: The iterative analysis resulted in 20 refined categories, structured under three overarching themes. This framework provided a comprehensive lens for understanding deep-tech commercialisation challenges.

Rationale for Refinement

The transition from 15 to 20 themes reflects the iterative nature of grounded theory. While the initial themes captured broad trends, further analysis revealed contradictions and nuanced barriers that required more precise classification. This process ensured that each category represented distinct, actionable insights rather than overly general groupings.

This structured approach strenghtens the practical relevance of the findings, directly informing the development of a Problem-Solution Fit (PSF) framework for deep-tech ventures.

To ensure transparency and replicability, Appendix C provides the full coding framework and summarised key insights for each of the 20 categories, offering a more detailed breakdown than presented in the main text.

With these refined themes established, the next section presents the key insights derived from stakeholder perspectives, illustrating how these challenges manifest in deep-tech commercialisation.

4.3 Synthesising Stakeholder and Hackathon Findings

This section present the findings from the qualitative research, structured into interview insights and Reverse Hackathon outcomes. The interviews provided a broad perspective on market challenges, organisational barriers, and industry dynamics affecting Problem-Solution Fit (PSF). The Reverse Hackathon built on these insights, by engaging stakeholders to co-create concrete, actionable problems that digital twin technology could address. Together, these methods offer a comprehensive foundation for refining the PSF process.

4.3.1 Interview Findings

The interview analysis identified three major themes that shape the journey toward PSF in deep-tech ventures:

1. Market Challenges: External barriers to digital twin adoption.
2. Organisational Barriers: Internal misalignments within deep-tech ventures.
3. Industry Dynamics: Broader trends and opportunities influencing adoption.

A structured table, following *Pratt (2009*), provides definitions and supporting quotes for each category. Below is a summary of key findings.

Market Challenges
The adoption of digital twin technologies is hindered by several persistent barriers. These challenges reflect the complexity of introducing innovative solutions into industries characterised by established practices, fragmented systems, and evolving regulatory demands. Proof quotes and definitions per category are described in Table 2.

Insights Summary

- Adoption Resistance: Organisations hesitate to integrate digital twins due to operational disruptions and resource demands.
- Cost Hesitation: High implementation costs and unclear business cases hinder investment, especially when return on investment (ROI) is difficult to quantify.
- Fragmented Data Systems: Lack of standardisation creates interoperability issues, limiting digital twins' effectiveness across supply chains.
- Supply Chain Complexity: Geopolitical tensions, low digitalisation, and sustainability pressures make improving transparency and resilience difficult.
- Regulatory Uncertainty: Evolving compliance requirements create hesitation, as companies struggle to align digital twin adoption with legal standards.
- Stakeholder Misalignment: Differences in technological understanding and priorities across stakeholders slow down collaboration and decision-making.
- Scalability Challenges: The broad applicability of digital twins makes defining clear, scalable use cases difficult, increasing competition with alternative solutions.

Category	Definition	Illustrative Quotes
Adoption Resistance	Organisations face significant operational disruptions and resource demands when integrating digital twins into legacy systems, limiting enthusiasm for adoption.	- "Everything is stuck in the old, previous systems that no one really understands." - *Data Architect, EDSN* - "Once you explain the steps for implementation, you get a 'no, we don't want that' answer." - *Supply Chain & Procurement, Van Oord* - "Implementing a solution in a whole supply chain has the obstacle that some actors in the chain can't really implement that technology." - *Value Chain Sustainability, RHDHV* - "Integrating with these ass-built networks is just a huge challenge." - *Data Architect, EPRI*
Cost Hesitation	High implementation costs, coupled with unclear business cases, hinder investment in digital twin technologies, especially in industries requiring clear ROI evidence.	- "It's a huge commitment on the price. Even internally you have to build business cases." - *Supply Chain & Procurement, Van Oord* - "Technical companies and innovations have really high stakes, there really are millions, hundreds of millions of investments in those industries." - *Data Architect, EDSN* - "I feel that currently between all companies and players doing something with digital twins, there is no clear business model for it." - *Supply Chain Resilience, Maersk*
Fragmented Data Systems	The lack of standardised practices creates interoperability challenges, hindering the effectiveness of digital twins across supply chains.	- "Automation in energy infrastructure we still find a little scary because the data quality is not yet good enough." - *Data Architect, EPRI* - "There is very little coordination in standardisation measures." - *Data Architect, EPRI* - "The challenge we are facing is that standardisation is currently the Wild West. There is not one authority creating standards for everyone. And in this sector, it's nearly impossible to create one standard fitting every use case." - *Data Architect, EDSN*
Supply Chain Complexity	Geopolitical tensions, low digitalisation levels, and sustainability pressures contribute to challenges in improving transparency and resilience.	- "Traditional logistics processes have been the same for a very long time." - *Supply Chain & Procurement, Van Oord* - "Actually, a lot of cargo owners and logistics companies have low digitalisation levels." - *Supply Chain Risk & Resilience, Maersk* - "It requires a lot of investment in infrastructures and devices, and all parties involved in the supply chain to work together." - *Supply Chain Risk & Resilience, Maersk*
Regulatory Uncertainty	Diverse and evolving compliance standards make it difficult for companies to confidently adopt innovative technologies without clear regulatory alignment.	- "It's hard to continue sustainability innovation because there are just too many insecurities in the direction that politics and regulations will develop." - *Innovation Manager, Vattenfall Heat* - "Compliance is a major thing for us as well, especially within the government." - *Supply Chain & Procurement, Van Oord* - "The government should really have a role in the energy transition by implementing regulations on energy efficiency." - *Innovation Manager, Vattenfall Heat*
Stakeholder Misalignment	Miscommunication and varying levels of technological understanding across stakeholders slow down collaborative efforts and innovations.	- "The biggest challenge we are facing right now is how do you change people's mindset to work with it?" - *Supply Chain & Procurement, Van Oord* - "Authorisation departments are always the ones making it difficult." - *Data Architect, EDSN* - "You need people beyond supply chain experts and tech, you need people in between that understand both parts and can translate." - *Supply Chain & Procurement, Van Oord* - "People are so focused on the process themselves, while the people in tech are not entirely sure what the process is. And the consequence is that a whole system is built that doesn't help." - *Innovation Manager, Vattenfall Heat*
Scalability Challenges	The broad applicability of digital twins creates difficulties in defining clear, scalable use cases and differentiating from other solutions.	- "There are a lot of general tech solutions out there, and companies see possibilities with them, but integrating it and fitting it to your specific company needs is always a hassle." - *Supply Chain & Procurement, Van Oord* - "Digital twin is a nice hype word. You can make it as big or small as you like. Plus, it seems easy for a company to claim to have an AI or digital twin tool, while on a lot of occasions that is an overstatement, and it's not clear what they use it for." - *Managing Director, Districon*

Table 2. Market Challenges with Definitions and Supportive Quotes

Organisational Barriers

Beyond external market challenges, deep-tech ventures face internal obstacles that hinder adoption and scaling. These challenges come from strategic misalignments, resource constraints, and leadership struggles. See Table 3 for illustrative quotes and full definitions per category.

Insights Summary

- Ambitions vs. Strategic Focus: Broad ambitions, combined with limited resources, result in inefficiencies and difficulties in articulating NexTwin's value proposition.
- Scaling Technology vs. Integration Challenges: While scalability is a goal, digital twins often require extensive customisation, making implementation complex.
- Leadership vs. Stakeholder Engagement: Leadership relies on passive strategies (e.g. online campaigns to gauge stakeholder interest) rather than direct, structured engagement with key industry players.
- Market Alignment vs. Value Proposition Clarity: While Docklab encourages innovation, it struggles to convey clear, outcome-driven benefits to both technical and business audiences.
- Technology Push vs. Market Demand: NexTwin's technology-first approach prioritises innovation over real world validation, delaying market traction.

Category	Definition	Illustrative Quotes
Ambitions vs. Strategic Focus	Docklab's broad ambitions are undermined by limited resources and unclear prioritisation, leading to inefficiencies in execution and difficulties in articulating NexTwin's value proposition effectively.	"We have limited resources and people for the larger number of projects that we have, so you automatically have a mismatch." - *Venture Development Manager, Docklab* "The only reason I see why NexTwin's commercialisation is delayed is because we just do multiple things at once."- *Head of Docklab* "We don't really have a dedicated market research team, so there is little focus on it." - *Docklab Venture Development Manager*
Scaling Technology vs. Integration Challenges	While scalability is a key objective, the need for significant customisation across diverse infrastructures complicates NexTwin's implementation.	"That's all because we just want to expand the business opportunities and the market focus." - *NexTwin Project Leader* "Integrating NexTwin in full supply chains will be much more complex than selling it as a stand-alone website." - *Venture Development Manager, Docklab*
Leadership vs. Stakeholder Engagement	Leadership's reactive strategies, such as online campaigns to gauge stakeholder interest, lack the proactive, market-driven focus needed for effective stakeholder engagement and decision-making.	"The campaign also has the goal of identifying the relevant market." - *Head of Docklab* "It's really a way for us to say; hey look at this page, and then hope that they will come to us, some sort of reversed market research." - *Docklab Venture Development Manager* "We hope that the 15k vouchers are a pull for companies to start a research project with us." - *Head of Docklab*
Market Alignment vs. Value Proposition Clarity	Although Docklab's iterative approach encourages innovation, it struggles to convey a clear, outcome-driven value proposition to both technical and non-technical audiences.	"From the company's perspective, we have this fail-fast approach. We want to publish as fast as possible, get responses, and then we iterate." - *NexTwin Project Leader* "The jargon, how we speak, is not a problem if we talk to tech people. But we're not going to speak to tech people." - *NexTwin Project Manager*
Technology Push vs. Market Demand	NexTwin's technology-first approach prioritises innovation over market feedback, creating misalignment with real-world needs and delaying commercial traction.	"It usually starts with a research project and then we develop some technical solution, which becomes our starting point." - *Head of Docklab* "So then we've worked ourselves into a certain direction, and validation for that direction comes later." - *Venture Development Manager, Docklab* "We wanted to explore blockchain as an emerging technology for supply chains, and in the consortium found a problem, that we then figured out how to solve with blockchain." - *SparkLab Project Manager (NexTwin's origin project)*

Table 3. Organisational Barriers with Definitions and Supportive Quotes

Industry Dynamics

The broader landscape of digital twin applications reveals significant opportunities, particularly in sustainability, operational efficiency, and governance. However, market entry requires tailores strategies. Definitions and illustrative quotes are provided in Table 4.

Insights Summary

- Sustainability-Driven Compliance: Regulatory pressures to meet net-zero targets is increasing demand for digital twins, but companies need measurable benefits before committing.
- Operational Efficiency through Automation: Digital twins can streamline operations and reduce waste, but adoption depends on demonstrating clear, industry-specific advantages.
- Tailored, Industry-Specific Solutions: Customised digital twin applications (e.g. in wind energy or logistics) are more appealing than generalised solutions.
- Data Visibility, Integration, and Standardisation: Interoperability improvements are critical to adoption, helping companies overcome data silos and meet regulatory requirements.
- Risk, Resilience, and Economic Viability: Digital twins can enhance predictive decision-making, but widespread adoption requires clear ROI.
- Collaborative Innovation and Governance: Cross industry collaboration and flexible governance structures facilitate data-sharing and compliance, opening strategic partnership opportunities for NexTwin.
- Strategic Influence on Value Chains for Sustainability: Large corporations with significant supply chain control can accelerate adoption of digital twins for sustainability and transparency.
- Traceability, Transparency, and Fraud Prevention in Supply Chains: Ensuring accountability in supply chains offers a strong market entry point for digital twins, especially in compliance-heavy industries.

Broader Implications for Deep-Tech Ventures

The interviews highlight common systemic challenges in commercialising deep-tech solutions, particularly in undefined markets with multiple stakeholders. Key takeaways include:

1. Systematic Stakeholder Engagement: Adoption depends on aligning interests across diverse stakeholders and addressing technological trust gaps.

2. Market-Driven Strategy over Technology Push: Deep-tech ventures must shift from developing solutions in isolation to validating problem-solution fit early on.

3. Clearer Value Propositions: Communicating measurable benefits, such as cost savings, regulatory compliance, and operational efficiency, reduces adoption resistance.

4. Collaborative Ecosystems: Tackling systemic issues like data standardisation and fragmented regulations requires strategic partnerships and shared governance models.

These findings informed the design of the Reverse Hackathon, which aimed to validate and expand on the interview insights by generating concrete, industry-driven problem areas. The next section presents the hackathon outcomes and their implications.

Category	Definition	Illustrative Quotes
Sustainability-Driven Compliance	Regulatory pressures to meet net-zero targets are driving demand for digital twins to track emissions and operationalise sustainability commitments. However, companies require clear, measurable benefits to overcome uncertainties about achieving these goals.	"A lot of companies signed up for net-zero in 2050, but they have no clue how to reach there." - *Managing Director, Districon*
Operational Efficiency through Automation	Digital twins hold potential to streamline operations, reduce waste, and enhance agility, but require tailored demonstrations of industry-specific benefits to gain traction.	"I see a lot of potential for digital twins in optimising daily operations, for production in factories for example." - *Value Chain Sustainability, RHDHV*
Tailored, Industry-Specific Solutions	Customised digital twin solutions addressing sector-specific challenges, such as wind energy or logistics, are increasingly in demand. A one-size-fits-all approach is insufficient for capturing market interest.	"Custom-built inventory solutions work really well when you develop it in-house, because you build it for a purpose." - *Supply Chain & Procurement, Van Oord*
Data Visibility, Integration, and Standardisation	Improved data management, interoperability, and standardisation are enablers for digital twin adoption, helping companies overcome data communication barriers and comply with regulatory requirements.	"If you would be able to find a unique identifier to bring different types of data together, then you'd have a really strong value proposition." - *Managing Director, Districon*
Risk, Resilience, and Economic Viability	Digital twins provide critical tools for risk prediction, resilience-building, and decision-making, but must deliver demonstrable ROI to justify adoption.	"Digital twins can help supply chain managers to make decisions, what the best options are that they could take to mitigate risks and their impact." - *Risk & Resilience, Maersk*
Collaborative Innovation and Governance	Cross-industry collaboration and flexible governance frameworks are essential for driving data standardisation and compliance, offering an area for NexTwin to establish strategic partnerships.	"Innovation also has to be in the way you collaborate with different parties." - *Innovation Manager, Vattenfall Heat*
Strategic Influence on Value Chains for Sustainability	Large organisations with significant supply chain influence can drive widespread adoption of sustainability practices, presenting an opportunity for NexTwin to target these key players.	"There is a lot to win in sustainability efforts, especially when talking about upstream material choices." - *Value Chain Sustainability, RHDHV*
Traceability, Transparency, and Fraud Prevention in Supply Chains	Enhanced accountability and fraud-proof systems represent a critical market entry point for digital twins, particularly in industries prioritising regulatory compliance and trust.	"If you can rule out fraud in your global supply chain solution, people will definitely get in line to pay for your digital twin." - *Value Chain Sustainability, RHDHV*

Table 4. Industry Dynamics with Definitions and Supportive Quotes

4.3.2 Reverse Hackathon Findings

The Reverse Hackathon provided a structured, collaborative approach to refining and validating insights from the interview phase. By engaging a internal and external stakeholders, the session not only confirmed key barriers to digital twin adoption, but also uncovered actionable opportunities for NexTwin. The findings are structured into three core areas (See Appendix D for the full documentation of insights):

1. Obstacle Analysis: Deepening understanding of adoption challenges.
2. Ideal Market Identification: Identifying sectors where NexTwin's capabilities align with urgent needs.
3. Role-Reversal Ideation: Exploring the value of NexTwin from different stakeholder perspectives.

This methodology proved valuable in translating broad industry challenges into specific, testable applications, further aligning NexTwin with real-world market needs.

Obstacle Analysis: Barriers to Adoption

Participants built on the interview findings, offering deeper insights into key obstacles to digital twin adoption:

- **Data Sharing and Integration:** Stakeholders emphasised mistrust in external systems and the difficulty of contextualising large data volumes. A participant noted,

  "The experts do it in a certain way which is normal work for them, but they can't even think of expressing it. Getting that out of them and into a system is extremely difficult." - Digital Transformation Expert, RHDHV

This reinforced the need for NexTwin to offer secure, context-aware solutions that simplify knowledge transfer.

- **Organisational Resistance:** Resistance due to fears of transparency and misaligned leadership priorities was highlighted. One participant remarked,
  "On an organisational level there is a lot of people that don't want transparency, because it demands accountability" - Supply Chain Expert, TUE

Overcoming resistance requires incremental, trust-building approaches that align with leadership incentives.

- **Incremental Implementation:** Participants stressed the importance of phased deployments to ease organisational resistance and improve usability. One participant noted,

  "I think it's best to have different smaller processes and then you take it process by process and then it becomes something bigger, than trying to tackle something big in one time." - Process Improvement, Port of Rotterdam

This underscored the value of modular implementation strategies to lower the barrier to adoption.

Ideal Market Identification: Where NexTwin Can Deliver Value

The session identified high-potential markets based on regulatory demands, operational complexity, and strategic importance.

- **Critical infrastructure**: Industries reliant on transparency and risk management tools, such as healthcare and energy, were prioritised. One participant observed,

  "These type of companies (bulk goods) and airports as well, if something happens, it impacts them immediately. So that's why I think these types of customers are interesting." - Digital Transformation Expert, RHDHV

Opportunity: NexTwin can support real-time risk assessment in high-stakes environments.

- **Resource Management and Sustainability:** Sectors requiring end-to-end visibility, such as bulk goods and emissions tracking, were highlighted as ideal targets. NexTwin's ability to enhance compliance and optimise resource usage resonated strongly with participants.

Opportunity: NexTwin can enhance compliance and optimise resource usage, making it valuable for sustainability-driven industries.

- **Transportation and Logistics:** Complex operational environments like ports and airports were noted as ready for digital twin adoption.

  "When everything comes together, it comes together in the port. And then the port must make sure they stay optimized for everyone. So, I think there's a lot there to gain." - Process Improvement, Port of Rotterdam

Opportunity: NexTwin can improve congestion forecasting and supply chain coordination.

Role-Reversal Ideation: Aligning with Stakeholder Needs

This exercise explored how different stakeholders perceive the value of digital twins, highlighting use cases that resonate most.

- Investment Decision-Makers: Participants emphasised the potential of digital twins for scenario planning and risk assessment, supporting better strategic investment decisions.

- Sustainability Managers: The tool's ability to simplify compliance and sustainability reporting resonated strongly, with the team stating, "Digital twins simplify compliance and sustainability reporting."

- Supply Chain Managers: The ability to mitigate risks such as fines and delays was a standout feature for this group; "It's not just cost reduction, it's about mitigating risks like fines and operational delays."

Prioritisation: High-Impact Opportunities

The session concluded with a ranking exercise, identifying top market opportunities based on alignment with NexTwin's capabilities and market readiness. The highest priority use cases included:

- Schiphol's Baggage Optimisation & Staff Planning: Improving operational efficiency in a major transportation hub
- Port of Rotterdam Congestion Forecasting: Reducing bottlenecks in one of Europe's busiest ports
- Ministry of Defence Supply Chain Visibility: Enhancing security and logistical efficiency in critical government operations.

These opportunities represent concrete, real-world applications where NexTwin can demonstrate immediate value and scalability.

Broader Implications of the Reverse Hackathon

The Reverse Hackathon validated key barriers and opportunities, reinforcing the importance of stakeholder-driven commercialisation. The findings underscore that deep-tech ventures cannot rely solely on technology-push strategies; they must align innovations with tangible industry needs. This method bridges the gap between theoretical insights and real-world market alignment by (1) Turning abstract challenges into actionable problem statements, (2) Identifying industries with strong demand for digital twin solutions, and (3) Ensuring stakeholder needs guide technology development. Beyond NexTwin, the Reverse Hackathon method provides a replicable methodology for other deep-tech ventures navigating early-stage commercialisation.

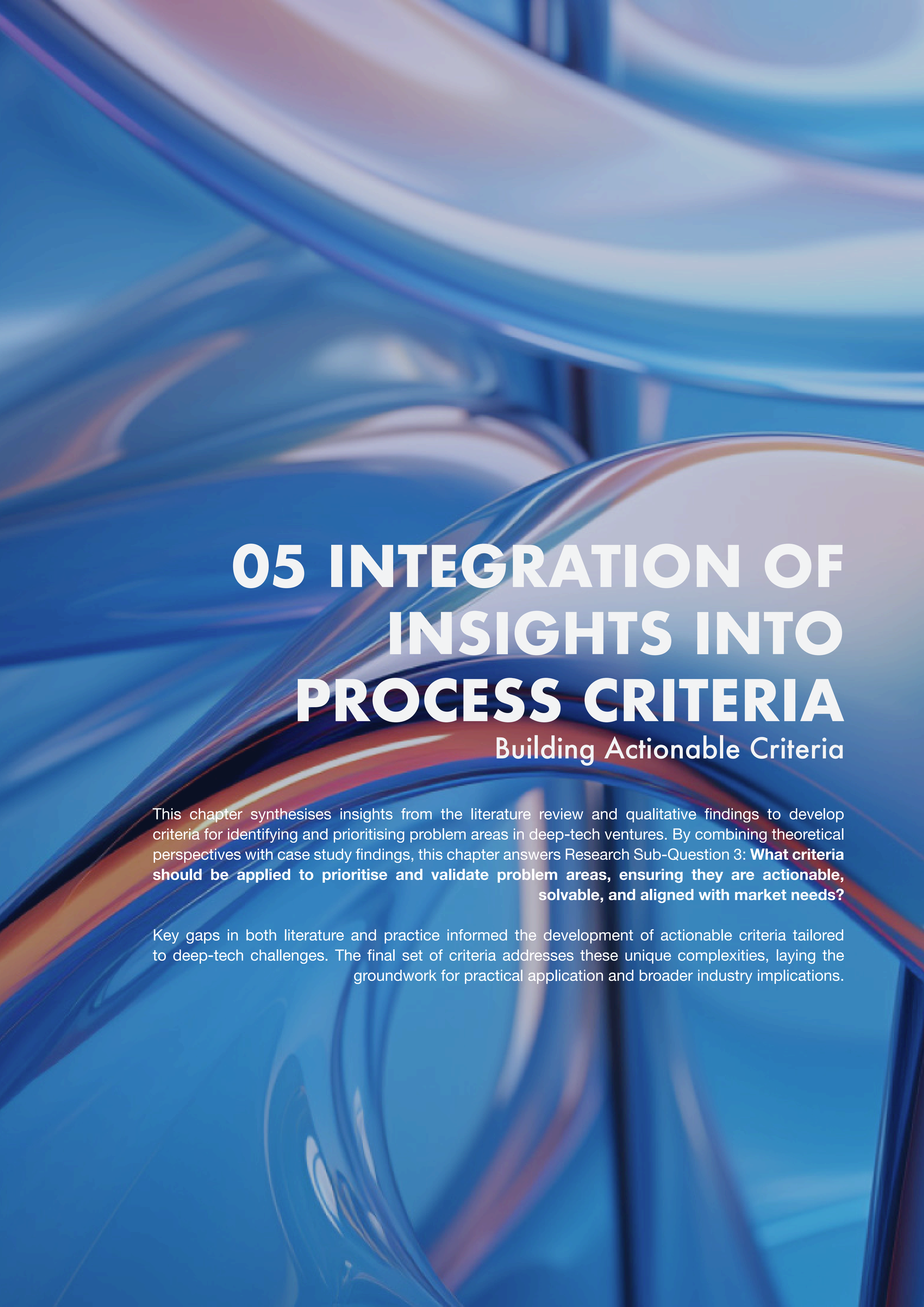
4.4 Concluding Chapter 4

This chapter explored the qualitative research findings, combining insights from semi-structured interviews and a Reverse Hackathon to examine how deep-tech ventures can systematically identify and prioritise high-impact problem areas. The interviews provided a detailed understanding of the challenges deep-tech ventures face, highlighting (1) Market Barriers, (2) Organisational Challenges, and (3) Industry Dynamics. The Reverse Hackathon added depth by validating these findings and generating actionable opportunities, highlighting the importance of structured stakeholder engagement and collaborative problem discovery.

These findings set the stage for Chapter 5, where the insights (see Table 4) are translated into a set of process criteria for achieving Problem-Solution Fit (PSF). The next chapter synthesises empirical insights from this research, and theoretical frameworks from the literature review, refining a structured approach for deep-tech ventures operating in tech-push contexts, bridging the gap between technology development and market adoption.

Phase	Key Insight	Iteration Outcome
Interviews	1. Stakeholders value measurable outcomes (e.g. ROI, compliance)	Highlighted the need for sector-specific value propositions
	2. Legacy systems and fragmentation are major barriers	Recognised the importance of simplifying integration strategies
	3. Early stakeholder engagement is critical but often passive and fragmented	Identified gaps in proactive engagement methods
Reverse Hackathon	1. Validation actionable problem areas, such as congestion forecasting and logistics planning	Refined criteria for actionable and scalable problem areas
	2. Co-creation clarified priorities and promoted shared ownership of ideas and opportunities	Demonstrated the importance of structured collaboration frameworks
	3. Stakeholders prefer phased pilots to demonstrate incremental value before large-scale adoption	Established phased pilot implementation as a part of the PSF process

Table 5. Summarising Insights and Their Impact on the Process



05 INTEGRATION OF INSIGHTS INTO PROCESS CRITERIA

Building Actionable Criteria

This chapter synthesises insights from the literature review and qualitative findings to develop criteria for identifying and prioritising problem areas in deep-tech ventures. By combining theoretical perspectives with case study findings, this chapter answers Research Sub-Question 3: **What criteria should be applied to prioritise and validate problem areas, ensuring they are actionable, solvable, and aligned with market needs?**

Key gaps in both literature and practice informed the development of actionable criteria tailored to deep-tech challenges. The final set of criteria addresses these unique complexities, laying the groundwork for practical application and broader industry implications.

5.1 Bridging Theory and Practice

This section connects insights from the literature review with findings from the case study, offering a structured analysis of the challenges and opportunities in achieving PSF for deep-tech ventures. The comparative evaluation highlights key overlaps, gaps, and refinements needed to create a set of process criteria.

1. Demand for ROI & Value Proposition Clarity

Literature Insights:

The literature underscores the importance of clearly communicating return on investment (ROI) to drive adoption, particularly for complex technologies (*Bobelyn et al., 2023*). Frameworks like Lean Startup (*Ries, 2011*) and Market Search Alliances (*Bruneel et al., 2020*) emphasise the role of outcome-driven messaging tools, such as ROI calculators and scenario-based demonstrations, in aligning innovations with market needs.

Case Study Insights:

Stakeholders consistently prioritised measurable outcomes, such as reducing operational delays or improving compliance. However, Docklab's broad value proposition lacked specificity, diluting its impact. The Reverse Hackathon reinforced the need for sector-specific applications, such as emissions tracking and congestion forecasting, to make the value proposition more relevant.

Key Gap:

While the literature highlights the need for clear ROI, it does not sufficiently address how deep-tech ventures should tailor their messaging to different industry contexts.

Informed Criterion:

Market Relevance: Solutions must align with industry-specific challenges to ensure adoption.

2. Legacy System Barriers & Perceived Product Complexity

Literature Insights:

Resistance to adopting new technologies is common in industries reliant on legacy systems, where integration costs, operational disruptions, and organisational passivity act as barriers (*Wittenburg & Strawn, 2021*). The literature suggests phased implementation strategies and partnerships with system providers as ways to mitigate these risks.

Case Study Insights:

Stakeholders cited integration complexity and operational disruptions as major concerns for adopting NexTwin. Internally, Docklab's positioning of NexTwin as a complex, multifaceted solution made adoption seem even more challenging. The Reverse Hackathon highlighted the need for phased pilots to demonstrate incremental value, aligning with stakeholders' preference for gradual adoption rather than an all-at-once implementation.

Key Gap:

The literature offers strategies for overcoming legacy barriers but does not emphasise the need to reframe product complexity to highlight ease of integration and modular functionality.

Informed Criterion:

Actionability: Solutions should be clearly implementable, emphasising ease of integration and phased adoption.

3. Multi-Stakeholder Decision-Making & Early Engagement

Literature Insights:

Multi-stakeholder environments pose challenges due to conflicting priorities, slow decision-making , and trust issues (*Lehtinen & Aaltonen, 2020*). Studies suggest that early stakeholder engagement and co-creation (*Liu et al. (2018)* and *Romme et al. (2023)* can align interests and accelerate adoption. However, the literature also notes that fragmented data ecosystems and unclear data-sharing agreements create further complexity. Industry consortia have been suggested as a way to standardise processes and promote collaboration (*Wittenburg & Strawn, 2021*).

Case Study Insights:

Docklab's early reliance on passive engagement methods, such as research vouchers, delayed alignment with key decision-makers. The Reverse Hackathon confirmed that data fragmentation and poor coordination were major barriers. Additionally, competitive sensitivities discouraged data sharing, reinforcing concerns in the literature about the difficulty of building trust in fragmented markets (*Bruneel et al., 2020*).

Key Gap:

While the literature highlights early engagement and co-creation, it does not fully address how data fragmentation and misaligned incentives amplify multi-stakeholder challenges. Without proactive frameworks for stakeholder coordination and standardisation, collaboration remains slow and inefficient.

Informed Criteria:

Stakeholder Alignment: Solutions should promote trust and shared ownership, and **Scalability:** Early efforts should create pathways for broader adoption.

These insights highlight the need for a systematic approach that integrates both theoretical and practical considerations. By addressing key gaps, such as value proposition clarity, integration complexity, and stakeholder coordination, this research refines a set of actionable criteria for Problem-Solution Fit (PSF).

The next section builds on these findings by introducing a structured set of process criteria to guide the identification and prioritisation of problem areas, ensuring they are aligned with stakeholder needs, market realities, and technological capabilities.

External Barrier	Internal Misalignment	Impact
Demand for ROI	Lack of clear value proposition	Stakeholders can't justify investment
Legacy system barriers	Complex product design	Adoption requires costly infrastructure
Multi-stakeholder decision-making	Lack of early stakeholder engagement	Delays in problem validation and decision-making
Data fragmentation	Poor stakeholder coordination	Misaligned data-sharing agreements and standards

Table 6. Summarising Concept Connections

5.2 Defining Criteria for Actionable PSF

To navigate the complexities of deep-tech innovations in a technology-push context, this section establishes four key criteria for identifying an dprioritising problem areas (see Figure 14). These criteria ensure that problem areas are not only technically feasible but also strategically aligned with market needs and stakeholder interests.

1. Actionability

Problem areas should be **clearly defined, specific, and feasible** to address using the venture's technological capabilities. Actionable problem areas provide a direct path from identifcation to implementation, reducing ambiguity and ensuring focus. For instance, the Reverse Hackathon demonstrated the importance of actionability by identifying port congestion as a well-defined challenge where NexTwin could deliver measurable value. In contrast, brapder, less-defined areas, such as "supply chain transparency", proved difficult to translate into concrete, implementable solutions.

Takeaway: Problem areas should be specific enough to guide solution development while remaining feasible given available resources and capabilities.

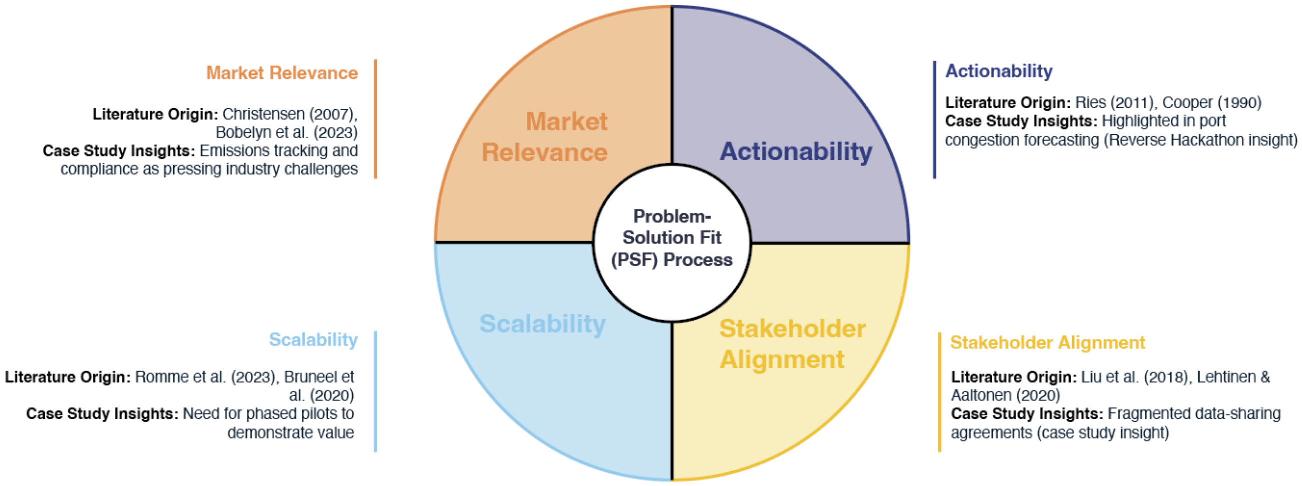
2. Stakeholder Alignment

Deep-tech innovations often involve **multiple stakeholders**, including industry partners, regulators, and end-users, each with their own priorities. Ensuring alignment across these groups is crucial for adoption. As seen in the case study, fragmented stakeholder coordination and inconcistent data-sharing practices slowed progress, reinforcing the need for structured engagement frameworks. Early collaboration and co-creation can help ventures navigate conflicting priorities, enable trust, and encourage shared ownership of solutions.

Takeaway: Structured stakeholder alignment reduces friction in decision-making and increases the likelihood of successful implementation.

3. Scalability

For a problem area to be worth pursuing, it must offer **potential for incremental growth and broader applicability**. Starting with small-scale pilots allows ventures to test solutions, refine approaches, and demonstrate value before committing to full-scale deployment.



Market Relevance

Literature Origin: Christensen (2007), Bobelyn et al. (2023)
Case Study Insights: Emissions tracking and compliance as pressing industry challenges

Actionability

Literature Origin: Ries (2011), Cooper (1990)
Case Study Insights: Highlighted in port congestion forecasting (Reverse Hackathon insight)

Scalability

Literature Origin: Romme et al. (2023), Bruneel et al. (2020)
Case Study Insights: Need for phased pilots to demonstrate value

Stakeholder Alignment

Literature Origin: Liu et al. (2018), Lehtinen & Aaltonen (2020)
Case Study Insights: Fragmented data-sharing agreements (case study insight)

Figure 14. Process Criteria with Attributions to their Origins

For example, Reverse Hackathon participants emphasised phased adoption as a critical enabler of scalability, particularly in industries where large-scale overhauls are impractical. Furthermore, stakeholders highlighted the importance of demonstrating early impact before securing long-term buy-in.

Takeaway: Prioritising scalable problem areas ensures that early investments lead to long-term, sustainable adoption.

4. Market Relevance

Problem areas should be **deeply connected to industry priorities**, ensuring that they resonate with decision-makers and create a compelling business case for adoption. For instance, discussions with stakeholders highlighted that industry leaders prioritise solutions addressing regulatory compliance, operational efficiency, and sustainability. Without strong market relevance, even technically sound innovations struggle to gain traction.

Takeaway: Solutions that directly address pressing industry challenges are more likely to secure stakeholder support and market adoption.

These four criteria serve as guiding principles for designing an effective PSF process tailored to deep-tech ventures. Among them, stakeholder alignment is a prerequisite for feasibility, ensuring that identified problem areas reflect the priorities of industry partners, regulators, and end-users. Lessons from the Docklab case study highlights that while these criteria provide a structured approach, they must be adapted to specific industry contexts for optimal impact. By applying these principles, deep-tech ventures can systematically bridge the gap between technological potential and market demand, increasing their chances of successful commercialisation.

5.3 Concluding Chapter 5

This chapter synthesised theoretical insights and practical case study findings to define clear criteria for prioritising problem areas in deep-tech ventures. By comparing existing frameworks with real-world challenges, three major gaps were identified, including the need for clear ROI communication, scalable solutions, and proactive stakeholder alignment. These insights informed the development of four key criteria: Actionability, Stakeholder Alignment, Scalability, and Market Relevance, which provide a structured foundation for achieving PSF in deep-tech commercialisation. The next chapter applies these criteria to design and refine the PSF process, demonstrating how they guide problem identification and validation in practice.

06 PROBLEM-SOLUTION FIT PROCESS

Designing a Replicable Process for Deep-Tech Innovation

This chapter answers Research Sub-Question 4: **What does a Problem-Solution Fit (PSF) process look like that supports deep-tech ventures align their capabilities with validated problem areas?**

Building on the criteria established in Chapter 5, this chapter outlines a structured PSF process designed to bridge the gap between technological potential and market needs. By integrating theoretical insights, case study findings, and iterative stakeholder engagement, the process provides a replicable framework for deep-tech ventures navigating early-stage commercialisation.

The chapter explores the design, validation, and application of the PSF process, with a focus on stakeholder alignment, iterative development, and practical implementation. The process is contextualised through its application within Docklab/NexTwin, illustrating how structured methodologies can transform abstract innovations into market-ready solutions.

6.1 Structuring the PSF Process for Deep-Tech Ventures

The PSF process was developed through an iterative approach, synthesising theoretical foundations, empirical findings, and hands-on facilitation experience from the Reverse Hackathon. By actively engaging stakeholders and refining insights at each stage, the process evolved into a structured yet flexible methodology that addresses key challenges in deep-tech commercialisation: stakeholder engagement, integration barriers, and strategic tensions between market-pull and tech-push.

From Criteria to Design
The foundation of the PSF process is built on four key criteria outlined in Chapter 5: **actionability, stakeholder alignment, scalability, and market relevance**. To translate these criteria into a practical framework, the Reverse Hackathon was selected as the core methodology due to its effectiveness in:

- Engaging stakeholders actively rather than passivle gathering insights.
- Validating assumptions through structured collaboration.
- Co-creating problem definitions that reflect industry realities.

Research by *Lee et al. (2020)* highlights the value of combining individual cognitive strategies with group collaboration improve problem discovery. The PSF process leverages this principle, ensuring that both personal expertise and collective validation shape the problem-definition process.

The PSF process incorporates insights from multiple disciplines to navigate stakeholder complexity, power imbalances, and fragmented decision-making. **Sociology** informs trust-building and effective communication, essential in multi-stakeholder environments. **Cognitive science** guides the structuring of individual and group activities, balancing independent reflection with collaborative synthesis to enhance problem discovery. **Design methodologies** guide the iterative refinement of problem areas, ensuring adaptability across different industries.

For example, each exercise in the Reverse Hackathon began with individual reflection, where participants outlined their assumptions, challenges, and priorities. This was followed by structured group discussions, where insights were shared, debated, and merged into co-created problem definitions. This dual-layered approach ensured that individual expertise was captured, misaligned perspectives were addressed, and actionable problem areas were validated in real-time.

Addressing Stakeholder Dynamics and System Fragmentation
Stakeholder feedback during interviews and the Reverse Hackathon revealed mixed perceptions of NexTwin's value proposition. While some stakeholders recognised its potential in addressing supply chain inefficiencies, others raised concerns about adoption barriers in fragmented ecosystems. The Reverse Hackathon surfaced these concerns early, allowing them to be addressed in the problem-definition stage rather than after development. This insight led to refinementsin how problem areas were prioritised and validated.

Takeaway: Facilitated co-creation and structured dialogue help bridge gaps in stakeholder engagement, ensuring that solutions are both desirable and feasible.

Additionally, the experience of organising and facilitating the Reverse Hackathon helped refine the process by observing stakeholder interactions, addressing logistical challenges, and refining activities iteratively to enhance engagement and outcome quality.

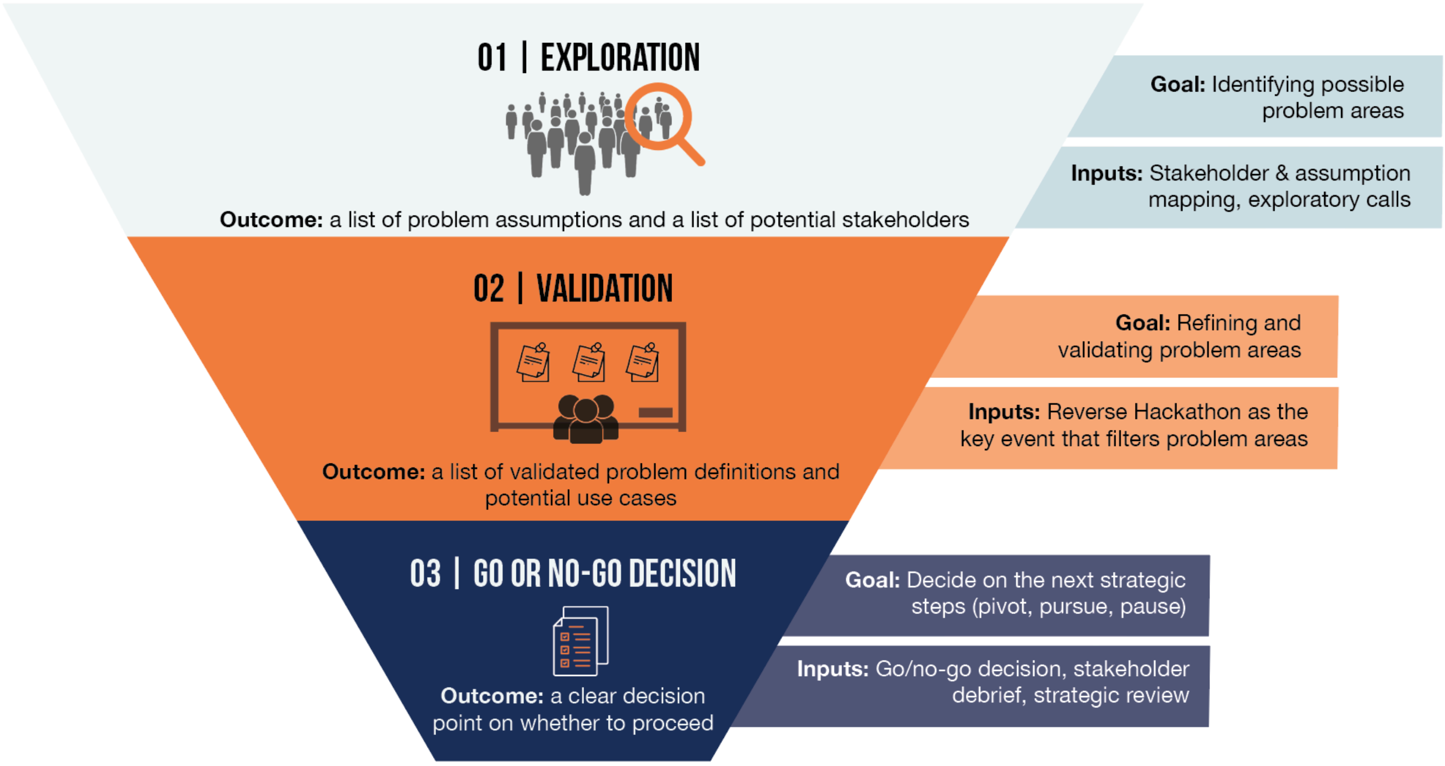


Figure 15. Funnel Visualisation of the Problem-Solution Fit Process

The PSF Process: Core Phases

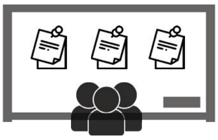
The Problem-Solution Fit PSF process consists of three interconnected phases, each addressing a specific challenge faced by deep-tech ventures. The phases are visualised in Figure 14.

1. Exploration Phase: Identifying Potential Problems

This phase establishes the foundation for problem discovery by mapping out industry challenges and aligning them with technological capabilities Key activities are stakeholder mapping, exploratory calls, and assumption mapping.

- **Objective:** Identify a range of potential problem areas and industry challenges.
- **Output:** A documented list of potential problems, initial assumptions, and stakeholder insights.

Example: Preliminary research and stakeholder interivews provided broad indications of how NexTwin's technology could be applied, such as inventory planning. These insights were vlaubale for identifying general industry pain points that could be turned actionable in the Reverse Hackathon.



2. Validation Phase: Refining and Testing Problems

This phase narrows the problem space by testing assumptions and prioritising high-impact challenges. The Reverse Hackathon is the core activity, where stakeholders collaboratively define, test, and refine problem areas.

- **Objective:** Narrow down potential problems to those that are actionable, relevant, and aligned with stakeholder needs.
- **Output:** A ranked list of validated problems, along with stakeholder feedback and potential use cases.

Example: During the Reverse Hackathon, the challenge of decision-making in multi-stakeholder environments was directly linked to the Port of Rotterdam, who experienced this exact issue. This made the broader challenge more actionable and concrete.

3. Decision Phase: Strategizing Next Steps

The final phase evaluates whether the identified problem areas align with the venture's strategic objectives. After the hackathon, it should be decided whether to process, pivot, or pause development.

- **Objective:** Provide a clear framework for decision-making regarding Problem-Solution Fit or alternative directions.
- **Output:** Go/No-go decisions, action plans, and stakeholder debriefs.

Example: NexTwin's team used scalability and market relevance criteria to eliminate problem areas that lacked long-term industrial potential, ensuring they focused on high-impact, high-adoption challenges.

Key Features of the PSF Process
The PSF process integrates sic key features that enhance its applicability across deep-tech contexts:

- Collaborative Engagement: The Reverse Hackathon ensures diverse stakeholder involvement, encouraging trust and alignment.
- Dual-Layered Strategies: Individual reflection and group collaboration ensure balanced problem discovery.
- Iterative Refinement: Embedded feedback allow continuous adaptation to new insights.
- Scalable Application: The process accommodates both exploratory and market validation across industries.
- Interdisciplinary Foundations: Sociology, cognitive science, and design thinking guide stakeholder engagement and problems structuring.
- Practical Tools: A structured guide organising a Reverse Hackathon is included in Appendix E.

The PSF process provides a systematic yet adaptable approach for bridging the gap between deep-tech innovations and market demand. By focusing on structured problem identification, iterative validation, and stakeholder collaboration, the process ensures that deep-tech ventures can proceed with clarity and confidence. The following sections will explore how this process was validated, refined, and applied to Docklab/NexTwin, demonstrating its real-world impact and scalability.

6.2 Validation and Refinement

The validation and refinement of the Problem-Solution Fit (PSF) process were conducted through iterative testing and stakeholder engagement, ensuring its applicability and effectiveness in deep-tech commercialisation. Using semi-structured interviews, direct observations from the Reverse Hackathon, and follow-up discussions, feedback was systematically integrated into the process. This iterative approach helped address three critical barriers in deep-tech ventures: stakeholder engagement, integration challenges, and strategic tensions between market-pull and tech-push. Each phase of the PSF process was tested, refined, and adapted based on real-world insights, ensuring a structured yet flexible approach to aligning deep-tech innovations with validated problem areas.

Testing the Phases of the PSF Process

1. Exploration Phase: Enhancing Market Problem Definition

During exploratory calls and stakeholder mapping sessions, initial assumptions about market challenges were tested. One key issue was that Docklab's problem definitions were too broad, making it difficult to assess feasibility. For example, initial problem statements like "Supply chain inefficiencies in energy markets" were deemed **too vague** by stakehholders, lacking clear industry-specific pain points.

How it was improved:
Structured prompts were added to the assumption mapping tool, requiring participants to contextualise challenges within specific industries (e.g. port congestion in biofuel supply chains). Industry-specific framing was incorporated, ensuring stakeholder engagement focused on concrete, actionable challenges rather than theoretical market assumptions.

2. Validation Phase: Strengthening Collaboration

The Reverse Hackathon was the central activity for refining and prioritising problem areas. However, early iterations had two key issues: prioritisation criteria were too complex, making it difficult for participants to assess feasibility, and strategic misalignment between NexTwin's capabilities and industry needs led to unrealistic problem selection.

How it was improved:

The problem ranking framework was streamlined to focus on three core criteria: **feasibility** (Can it be solved now?), **relevance** (Is it a critical industry challenge?), and **urgency** (Does solving it create immediate value?). This simplified decision-making while maintaining rigour. Also role-reversal exercises were expanded, requiring participants to argue against their own problem selections. This forced deeper analysis and exposed mismatches between industry priorities and NexTwin's capabilities.

3. Decision Phase: Clarifying Next Steps

Early Go/No-go decision-making exercises revealed that vague strategic objectives made it difficult to determine whether to proceed, pivot, or pause. Initial discussions often lacked structure, leading to decisions based on gut feeling rather than clear criteria.

How it was improved:

A structured decision matrix was introduced, assessing potential projects based on:

- **Alignment with organisational goals** (Does this fit Docklab's mission and capabilities?)
- **Market needs** (Does it address a validated industry problem?)
- **Resource availability** (Do we have the capacity to pursue this opportunity?)

Each problem area was rated on these criteria using a scoring system, helping participants determine whether to proceed, pivot, or pause.

Also a stakeholder debrief template was added, ensuring that feedback from external partners was captured and factored into decisions.

These refinements ensured that decisions were data-driven, transparent, and strategically aligned rather than reactive.

Incorporating Feedback into the PSF Process

The iterative refinement of the PSF process relied on feedback loops at every stage, ensuring continuous improvement:

- Post-Session Debriefs: Following the Reverse Hackathon, participants were invited to share feedback on the session structure, activities, and outcomes.
Insights included suggestions for combining the ideal market identification and obstacle elimination exercises, and introducing more visual aids to facilitate co-creation.
- Validation Metrics: Metrics such as participation rates, problem prioritisation outcomes, and alignment with organisational goals were tracked to measure the effectiveness of the process. For example, the number of actionable problem areas identified during the Reverse Hackathon served as a key indicator of success.

Key Lessons from the Validation Process
Several lessons emerged during the validation and refinement stages, informing adjustments to the PSF process:

- Participant Selection: Targeted invitations and clear pre-event communication ensured diverse, relevant participation. Framing participants as “industry experts” increased engagement, while structured facilitation balanced discussions and promoted collaboration.

- Preparation and Facilitation: Including problem prompts, stakeholder briefings and visual tools enhanced clarity and focus. Timeboxing activities maintained energy, while clearly defined goals and templates ensures actionable outcomes.

- Addressing Strategic Tensions: The role-reversal exercise proved particularly effective in addressing market-pull vs tech-push tensions, helping participants balance immediate industry needs with the potential capabilities of NexTwin.

These refinements created a more structured, adaptable, and outcome-driven framework, equipping it to handle different industry contexts and challenges. The following section will demonstrate how the PSF process was applied to Docklab, illustrating its effectiveness in addressing real-world market challenges.

6.3 Implementation at Docklab

Docklab has implemented the refined Problem-Solution Fit (PSF) process to focus its commercialisation efforts on a beachhead market: the chemicals industry. This targeted approach addresses systemic challenges by prioritising stakeholder engagement, refining value propositions, and transitioning from technical to market validation.

1. Focusing on a Beachhead Market

To enhance commercial traction, Docklab has chosen the chemicals industry as its high-priority market. This decision aligns with the sector’s regulatory and operational challenges, making it a strong candidate for NexTwin’s capabilities.

To validate this focus, Docklab is organising another Reverse Hackathon, which will involve industry experts to co-create and prioritise actionable problem statements. This event aims to ensure that NexTwin addresses industry-specific pain points, validates market assumptions, and engages stakeholders early to enable collaboration and buy-in.

2. Refining the Value Proposition

A critical challenge for Docklab has been translating NexTwin’s broad capabilities into industry-specific value propositions. While the researcher’s advice was this refinement, further iteration is needed to ensure alignment with the chemicals sector.

The upcoming Reverse Hackathon will provide real-time industry feedback, ensuring that NexTwin’s messaging moves from broad decriptions to clear, actionable benefits, addresses specific stakeholder concerns, and emphasises measurable outcomes.

Achieving desirability remains a critical challenge. Stakeholders have expressed mixed views on NexTwin’s relevance, with some recognising its potential for efficiency gains, while others question the broad use of ‘digital twin’, highlighting concerns about its relevance and differentiation.

Docklab must demonstrate NexTwin's industry-specific benefits rather than relying on generic digital twin technology. Next to this, value propositions should align with operational priorities, ensuring that NexTwin's capabilities directly solve industry pain points.

3. Shifting from Technical to Market Validation

Historically, Docklab has focused on technical proofs of concept to validate NexTwin capabilities. However, without early stakeholder buy-in, technical feasibility alone does not guarantee adoption. To bridge this gap, Docklab is transitioning to a balanced approach between tech-push and market-pull, implementing the Reverse Hackathon into their development process.

Outcomes for Docklab

- Implementing the Process: The PSF Process has become a recurring strategy for structured stakeholder engagement, enabling continuous market validation.
- Strategic Clarity: Docklab's approach is now structured around exploration, validation, and decision-making phases, rather than an open-ended search for applications.
- Improved Market Fit: By aligning NexTwin's capabilities with specific needs in the chemicals industry, Docklab is in a stronger position to deliver actionable solutions that meet real market demands.

By embedding the PSF process into its commercialisation strategy, Docklab has transitioned from an exploratory approach to a proactive, market-driven model. This shift increases the likelihood of successful and sustainable adoption for NexTwin by ensuring that future developments are grounded in validated industry challenges rather than speculative technological applications.

6.4 Concluding Chapter 6

Chapter 6 presented the Problem-Solution Fit (PSF) process, a structured framework designed to help deep-tech ventures align their innovations with validated market needs. While the process was developed for broad applicability, Docklab served as a single case study to test and refine its key components. The PSF process emphasises value proposition refinement, proactive stakeholder engagement, and shifting from technical validation to market-driven validation.

Key Takeaways:

- Focusing on a single beachhead market increases strategic clarity.
- The Reverse Hackathon helps to identify and validate problem areas before resource allocation.
- The PSF process reduces uncertainty by ensuring that solutions are grounded in real industry needs.

This chapter laid the groundwork for understanding how a structured PSF process contributes to deep-tech commercialisation. The next chapter expands on the broader contributions of the PSF process, discussing its academic relevance, practical implications, and limitations. It also highlights opportunities for future research and refinement.

07 DISCUSSION

Reflecting on Contributions, Implications, and Future Research Directions

This chapter examines the broader implications of this research, evaluating how the Problem-Solution Fit (PSF) process contributes to academic literature and provides practical insights for deep-tech ventures navigating early-stage commercialisation. It also discusses the study’s limitations and constraints whil identifying opportunities for future research to enhance the applicability and scalability of the PSF framework. By situating the findings within the broader context of deep-tech innovation, this discussion highlights their relevance, impact, and potential pathways for further exploration.

7.1 Advancing Deep-Tech Commercialisation

This research contributes to the academic discourse on deep-tech commercialisation by addressing critical gaps in existing methodologies for achieving Problem-Solution Fit (PSF). While prior frameworks, such as those proposed by *Romme et al. (2023)* , emphasise scaling through ecosystem engagement and talent acquisition, this study shifts the focus to PSF as a foundational step.

In technology-push contexts, where market needs are ambiguous, early problem identification and validation are essential to avoid resource misallocation. By integrating insights from sociology, innovation management, and design methodologies, this study refines and extends existing theories, emphasising PSF as an essential early-stage process for commercial success.

Key Contributions

1. Establishing PSF as a Crucial Early-Stage Process

This research underscores Problem-Solution Fit (PSF) as a critical step in bridging the gap between technological development and market alignment. While existing models prioritise scalability, they often overlook the risks of developing solutions without validated demand. This study provides a structured process for validating market needs early, ensuring that deep-tech ventures do not invest heavily in technologies that lack clear applications. Insights from sociology, such as *Granovetter's (1985)* trust-building theory, reinforce the importance of stakeholder alignment in fragmented, multi-stakeholder environments.

Key takeaway: A PSF-first approach minimises the risk of commercial failure by ensuring alignment before scaling efforts begin.

2. Advancing the Reverse Hackathon as a Validation Tool

This research expands the concept of the Reverse Hackathon, originally based on *Romme et al.'s (2023)* method (also referred to as "Fastrackathon"), by reframing early-stage commercialisation as a collaborative, stakeholder-driven process. Shifting from passive validation to active co-creation, the Reverse Hackathon enables stronger connections between ventures and their ecosystems. This interdisciplinary method strengthens stakeholder engagement and problem validation.

Key takeaway: The Reverse Hackathon accelerates the identification of actionable problem areas while enhancing stakeholder collaboration, making commercialisation efforts more relevant and feasible.

3. Refining Sector-Specific Value Proposition Development

The research highlights the importance of sector-specific value proposition development, particularly in industries with strict regulatory and operational constraints. Many deep-tech ventures struggle with broad, undefined messaging, which fails to resonate with industry decision-makers. This study introduces practical strategies for refining value propositions based on early stakeholder input.

Key takeaway: Tailoring value propositions to sector-specific drivers, such as regulatory compliance, efficiency, and risk mitigation, increases market readiness and adoption potential.

4. Addressing the Challenges of Tech-Push Commercialisation

Unlike methodologies such as Lean Startup *(Ries, 2011)* or Design Thinking *(Kelly & Littman, 2001)*, which assume a pre-existing understanding of market needs, this research provides structured tools for navigating the ambiguity of tech-push ventures. By structuring exploratory and validation phases, it supports ventures in identifying and aligning with actionable problem areas, reducing the risk of investing in solutions that lack industry relevance.

Key takeaway: The PSF process supports deep-tech ventures in structuring their commercialisation efforts, even when market demand is unclear or evolving.

5. Creating a Flexible and Scalable Framework

The PSF process developed in this research is adaptable across industries and organisational scales. Unlike ecosystem-centric models, such as *Romme et al.*'s focus on Eindhoven, the PSF process applies to fragmented or resource-constrained environments. Whether for start-ups, research-driven ventures, or corporate innovation teams, the modular structure allows for scalability.

Key takeaway: The flexibility of the PSF process enables its application beyond a single industry or ecosystem, making it a replicable tool for deep-tech commercialisation worldwide.

Addressing Literature Gaps

This study advances deep-tech commercialisation research by integrating and extending *Romme et al.'s (2023)* framework, with a stronger focus on early-stage PSF. It bridges the gap between technology and market readiness, provides actionable methodologies for problem identification, stakeholder engagement, and value proposition refinement, and offers tools for navigating navigating tech-push commercialisation. This research lays the foundation for practical applications and further academic exploration, which are discussed in the following sections and summarised in Table 7.

7.2 Practical Implications for Deep-Tech Ventures and More

The Problem-Solution Fit (PSF) process, while refined through Docklab's experience with NexTwin, is designed to be universally applicable across industries and organisations. It offers structured tools to help deep-tech ventures align technological innovations with actionable market needs, reducing uncertainty and increasing the likelihood of commercial success. This section outlines key applications of the PSF process, providing practical guidance on how deep-tech ventures can implement and scale these strategies.

Key Applications for Deep-Tech Ventures

1. Leverage the Reverse Hackathon for Early Problem Validation

The Reverse Hackathon is a structured, collaborative method for uncovering and validating problem areas by engaging internal teams, industry stakeholders, and external experts. By facilitating creative exploration, it surfaces hidden challenges and align technological solutions with real-world industry needs. This approach shifts the focus from passive validation methods to active co-creation, integrating different stakeholder perspectives to ensure solutions are feasible, relevant, and demand-driven. It encourages creative exploration, because participants explore future scenarios rather than react to predefined assumptions, and it reduces misalignment risk, because ventures get real-time industry feedback, avoiding costly pivots later.

Advice for Implementing a Reverse Hackathon

- Timing: Schedule early in the exploration phase to engage stakeholders, including potential clients, innovation leaders, and technical experts in co-defining industry challenges.
- Use Imaginative Prompts to encourage stakeholder creativity and deep insights:

"If [technology] were to enter a market where [specific barrier] is minimised, what would that market look like?"

"Who are the key stakeholders, and how do they interact?" "What urgent problem does [technology] solve for them?"

- Document Outcomes: Capture all session outputs, including stakeholder feedback and insights, co-created problem definitions, and refinements.

2. Prioritise Stakeholder Engagement and Feedback Loops

Early and targeted stakeholder engagement is critical to reducing false starts and identifying viable problem areas. By focusing on industry experts and potential users, ventures can gain clarity on market needs and refine their focus before committing significant resources. Research by *Stoll et al. (2020)* highlights that proactive stakeholder engagement increases alignment with industry neeeds.

Advice for Engaging Stakeholders Effectively

- Conduct 3-5 exploratory calls with industry experts or potential users, asking "If you had access to this technology, what problem would you solve with it?"
- Focus on pain points rather than technical features. Frame discussions around operational challenges, regulatory bottlenecks, and efficiency gaps.
- Log insights systematically: Use a structured approach to capture stakeholder feedback, helping recognise patterns across conversations.

3. Apply a Problem Prioritisation Matrix

To focus resources efficiently, deep-tech ventures should apply a prioritisation matrix (see Figure 15) to evaluate potential problem areas based on feasibility, market/regulatory pull, urgency, and strategic fit. It prevents teams from spreading resources too thin, ensures efforts are focused on high-impact, high-adoption areas, and helps teams in the go/no-go decision.

4. Develop Playbooks and Reusable Resources

Institutionalising the PSF process within an organisation ensures that it remains scalable, repeatable, and adaptable. Playbooks can standardise processes, making them easier to implement across teams and projects. Templates reduce onboarding time, helping new team member engage with the methodology quickly, while continuous updates keep strategies relevant and refined based on evolving industry needs.

Advice for Building Playbooks & Templates

- Include step-by-step guidance for Reverse Hackathons, exploratory calls & stakeholder interviews, and problem prioritisation exercises.
- Incorporate real-world examples from past projects to demonstrate practical applications.
- Regularly update playbooks with new insights from subsequent projects, ensuring that the PSF process evolves over time.

High impact, low feasibility **BIG BETS**	High impact, high feasibility **QUICK WINS**
Low impact, low feasibility **TIME WASTERS**	Low impacy, high feasibility **NICE-TO-HAVE**

Figure 16. Prioritisation matrix adapted from Eisenhower's (1954) Decision Matrix, which organises tasks by urgency and importance

The PSF process provides deep-tech ventures with a practical, repeatable framework for overcoming commercialisation challenges. Whether applied in research labs, start-ups, or corporate innovation teams, it can enable ventures to make informed, data-driven decisions, increasing their chances of achieving sustainable commercialisation and market success.

However, while the PSF process provides an approach to deep-tech commercialisation, its strategic implementation varies across different contexts. The next section examines its implications for Docklab, followed by a discussion on its limitations and opportunities for further refinement.

Contribution Area	Academic Contributions	Practical Contributions
Positioning PSF as a Critical Early-Stage Process	Expands on existing frameworks by explicitly establishing PSF as a foundational step for deep-tech commercialisation. This extends Romme et al.'s (2023) work by focusing on structured problem discovery rather than just application scouting.	Provides a structured and replicable process for systematically identifying, prioritising, and validating actionable problem areas, reducing resource misallocation in early-stage deep-tech ventures.
Advancing Reverse Hackathons for Problem Validation	Extends the Reverse Hackathon beyond its original focus on tech-to-market alignment by applying it as a structured approach for problem validation in ambiguous, multi-stakeholder environments. Emphasises co-creation in defining and refining problem areas rather than solely exploring technological applications.	Demonstrates how Reverse Hackathons can serve as a stakeholder-driven tool for deep-tech problem validation, offering a practical framework for aligning emerging technologies with concrete industry needs.
Addressing Stakeholder Dynamics	Explores trust-building and collaboration in fragmented systems, integrating insights from sociology and case findings.	Recommends strategies for early engagement and structured coordination to align stakeholder priorities.
Refining Value Propositions	Extends understanding of value proposition design by addressing regulatory and operational drivers.	Provides practical templates to tailor value propositions to specific market needs and challenges.
Supporting Scalability	Proposes scalability as a key criterion for sustainable adoption of solutions in deep-tech ventures.	Recommends phased pilots and industry collaboration to ensure long-term impact and adoption.

Table 7. Academic and Practical Contributions of the PSF Process

7.3 Strategic Implications for Docklab

This thesis tested the Reverse Hackathon as a method for Docklab to identify Problem-Solution Fit (PSF) for deep-tech ventures like NexTwin. The findings emphasised the importance of structured stakeholder engagement, targeted value proposition development, and iterative validation through recurring sessions. As a result, specific strategic recommendations were given to refine Docklab's approach to commercialisation.

1. Adopting the Reverse Hackathon for PSF

The Reverse Hackathon was introduced and tested as a practical tool for aligning NexTwin's capabilities with actionable problem areas. This approach demonstrated its effectiveness in fostering co-creation, surfacing hidden challenges, and engaging stakeholders directly. Following the results of this thesis, Docklab formally adopted the method as a recurring strategy to ensure continuous problem validation. This allows Docklab to stay aligned with evolving industry challenges while refining NexTwin's positioning in response to real stakeholder needs.

2. Refined Strategic Focus and Industry Choice

A major outcome of this research was the recommendation for Docklab to narrow its market focus and tailor its value proposition accordingly. Rather than pursuing a broad, industry-agnostic approach, Docklab was encouraged to select a high-potential industry where they could offer measurable benefits. This led to the selection of the chemicals industry as a beachhead market, chosen for its alignment with NexTwin's potential to address sustainability and compliance challenges, and the amount of connections Docklab has in this industry.

To validate this strategic shift, Docklab organised another Reverse Hackathon specifically for stakeholders in the chemicals sector. This event built on the framework tested in this research, refining industry-specific problem areas relevant to NexTwin. By applying the PSF process within a focused industry, Docklab is increasing its chances of establishing relevance and a strong foothold here.

3. Institutionalising a Proactive Approach

Beyond immediate strategic choices, this thesis underscores the need for Docklab to institutionalise a more structured and iterative approach to commercialisation. The reserach revealed that stakeholder alignment and value proposition clarity were ongoing challenges, ones that required continuous refinement rather than a one-time adjustment. The Reverse Hackathon provided a tool for recurring engagement, allowing Docklab to directly address stakeholder pain points rather than assuming industry needs.

This transition represents a fundamental shift in how Docklab approaches commercialisation with NexTwin, strenghtening its ability to make informed decisions, allocate resources efficiently, and enhance NexTwin's market viability.

By applying the tested Reverse Hackathon methodology and integrating these recommendations, Docklab is not only advancing its commercialisation efforts for NexTwin but also setting an example for how deep-tech ventures can leverage proactive stakeholder engagement and iterative refinement. It shows how structured engagement can de-risk commercialisation efforts and create long-term strategic clarity.

7.4 Limitations

While this research provides valuable insights into the commercialisation of deep-tech ventures, certain limitations must be acknowledged, reflecting the scope, methods, and constraints of the study.

1. Market Validation

Due to time constraints and the exploratory nature of the research, full market validation, such as pilot testing and longitudinal studies, was beyond the study's scope. Instead, the research focused on designing a structured process for deep-tech ventures transitioning from a "solution looking for a problem" to a commercially viable product. Future should implement and test the Problem-Solution Fit (PSF) process in real-world applications to assess its effectiveness in guiding ventures toward validated market opportunities.

2. Generalisability

The PSF process was developed with a focus on deep-tech ventures operating in uncertain environments, particualrly those facing undefined problem areas and multi-stakeholder complexities. However, its development was shaped by Docklab's specific focus on supply chain optimisation and venture studio operations, limiting its broader applicability.. The process may be less effective in contexts where:

- Industries operate under rigid regulatory frameworks, leaving little room for exploratory problem identification.
- Ventures already have well-defined problem areas, making structured problem discovery less necessary.

While adaptable, the process requires further validation in industries with different market dynamics to assess its broader applicability.

3. Methodological Constraints

Several methodological choices influenced the research outcomes:

- Design Science approach: While effective for iterative problem-solving, its reliance on artefact development may have limited external validation in real-world settings.
- Double-Diamond framework: This structured framework provided a clear process, but sometimes oversimplified the iterative and non-linear nature of stakeholder engagement.
- Reverse Hackathon: This approach facilitated co-creation and validated insights, but required facilitation expertise and stakeholder availability, which could limit its scalability in resource-constrained settings.
- Semi-Structured Interviews: These provided rich qualitative data, but insights were influenced by participants availability and self-reported biases, potentially leaving gaps in stakeholder perspectives.

Future research could complement these methods with quantitative validation, controlled experiements, or longitudinal studies to strengthen reliability.

4. Data Limitations

Access to detailed operational data from potential customers was restricted, limiting the depth of analysis. The study relied on qualitative insights from interviews and workshops, and publicly available information on industry trends. While these sources provided valuable context, richer datasets or long-term tracking of ventures using the PSF process could strengthen future assessments of its impact.

5. Unintended Consequences of Deep-Tech Adoption

The adoption of deep-tech solutions (e.g. digital twins) offers clear benefits in efficiency, transparency, and sustainability compliance. Howevert, unintended consequences must also be considered. These include increased energy consumption from processing large-scale data *(Lange et al., 2020)*, risks of data privacy breaches *(Losavio et al., 2018)*, and over-reliance on automated systems, potentially reducing human oversight in critical operations *(Parasuraman & Wickens, 2008)*. Integrating environmental impact assessments and ethical considerations into the PSF process could ensure that commercialisation strategies align with broader sustainability and societal goals.

6. Exploratory Scope

This research prioritised early-stage challenges, specifically Problem-Solution Fit, rather than the entire commercialisation lifecycle. As a result, later stages such as scaling and long-term adoption, remain outside the study's scope. Future research could examine how ventures transition from PSF to full-scale market entry and sustained growth.

7. Time and Resource Constraints

The iterative development and testing of the PSF process were constrained by the research timeframe and available resources. While the process was refined through stakeholder engagement, additional iterations and real-world applications could enhance its effectiveness.

These limitations highlight areas where further exploration and refinement of the PSF process are needed. The next section outlines specific recommendations for future research to address these constraints and build on the findings of this study.

7.5 Future Research Directions

The findings of this thesis open different directions for further research to refine and extended the Problem-Solution Fit (PSF) process. Future studies could enhance the framework's adaptability, deepen its theoretical foundations, and address challenges identified in this research. The following areas offer promising directions for continued exploration:

1. Refining and Scaling the PSF Process

Future research should test the PSF framework across a broader range of industries and contexts to evaluate its adaptability and scalability. Sectors such as healthcare, logistics, and energy, present unique complexities, including regulatory constraints and multi-stakeholder dependencies. Comparative studies across industries could highlight context-specific adaptations and refine the process into tailored tools for different deep-tech domains.

2. Building Trust in Multi-Stakeholder Ecosystems

Fragmented stakeholder ecosystems remain a significant barrier for deep-tech ventures. Future studies could explore strategies for fostering trust, incentivise data-sharing, and establish governance mechanisms in competitive environments. Practical investigations into collaborative models in supply chains, energy, and logistics could provide actionable insights into overcoming stakeholder misalignment and enabling data-driven cooperation.

3. Balancing Tech-Push and Market-Pull Dynamics

This study higlighted the importance of market-driven validation, but the balance between market-pull and tech-push strategies remains an open question. Future research could examine when and how ventures should shift between these approaches, helping start-ups allocate resources effectively. Case studies on deep-tech ventures navigating uncertain or emerging markets could reveal key decision-making turning points that impact commercial success.

4. Leveraging Regulations & Sustainability
Evolving regulations and sustainability mandates are increasingly shaping the adoption of deep-tech innovations. *Porter and van der Linde (1995)* argue that environmental regulations can stimulate innovation by encouraging firms to develop cleaner, more efficient technologies. Future research could explore (1) how ventures can better align with regulatory compliance to accelerate adoption, (2) how sustainability drivers, such as carbon neutrality goals and circular economy frameworks, influence investment and market entry, and (3) the role of public-private partnerships and certification programs in supporting market positioning and long-term viability.

5. Standardising Co-Creation Tools
The Reverse Hackathon proved effective for early-stage validation, but its broader applicability requires further exploration. Future research could focus on (1) adapting and standardising the method for use across different industries and stages of innovation, (2) assessing its ability to accelerate stakeholder alignment and streamline problem discovery, and (3) develop evaluation metrics to measure its effectiveness and potential impact on deep-tech ventures success.

6. Longitudinal Studies on PSF Adoption
Future research could assess the long-term impact of the PSF process by tracking ventures that implement it over multiple years. Longitudinal studies could provide valuable insights into (1) how PSF influences market entry, scalability, and funding acquisition, (2) whether ventures that follow the process experience higher adoption rates and reduced commercialisation risks, and (3) how iterative refinements of the PSF process affect venture longevity and adaptation to evolving market conditions.

Expanding research in these areas will strengthen the PSF process and contribute to the broader discussions on innovation management, commercialisation frameworks, and venture development.

7.6 Concluding Chapter 7

Chapter 7 explored the broader implications of this thesis, highlighting its contributions to academia and practical applications for deep-tech ventures. The Problem-Solution Fit (PSF) process was positioned as a structured method for aligning deep-tech innovations with actionable market needs, addressing critical gaps in early-stage commercialisation. While the study's limitations, such as the lack of full market validation and generalisability across industries, were acknowledged, the chapter identified key areas for future research, including refining the PSF process, developing strategies for multi-stakeholder collaboration, and exploring regulatory and sustainability incentives as commercialisation drivers.

These insights reinforce the PSF process' as a valuable tool for deep-tech ventures, offering a structured approach to overcoming the “solution looking for a problem” challenge. The next chapter summarises the study's key findings and answers the central research questions.

08 CONCLUSION

Summarising Insights and Steps for Deep-Tech Success

This chapter synthesises the key findings of the research, outlining how the Problem-Solution Fit (PSF) process addresses critical challenges in deep-tech commercialisation. It revisits the study's main insights, answers the research questions, and reflects on broader implications. The chapter concludes with final remarks on the significance and future potential of the PSF process.

8.1 Summary of Key Findings

This research set out to explore why deep-tech ventures struggle to achieve Problem-Solution Fit (PSF), particularly in technology-push contexts where market needs are ambiguous. Through a structured methodology incorporating the Double Diamond framework, Design Science approach, and an extended single case study, the study developed and validated a replicable PSF process for aligning deep-tech innovations with real-world problems.

The study's key insights are:

1. Early Validation is Essential for Deep-Tech Success

Early-stage validation plays a critical role in bridging the gap between technological potential and market needs. The Reverse Hackathon, adapted for this resesarch, proved effective in uncovering hidden pain points and ensuring stakeholder-driven problem identification. Unlike traditional market validation, which often focuses on testing existing solutions, this method prioritises identifying meaningful, solvable problems before product development advances.

2. Co-Creation Accelerates Market Alignment

The research confirmed that collaborative, iterative processes are esesntial for dep-tech ventures operating in fragmented ecosystems. The Reverse Hackathon, inspired by *Romme et al.'s (2023)* framework, successfully engaged diverse stakeholders in defining and validating problem areas. This co-creation approach not only strengthened problem identification but also enabled stakeholder buy-in, increasing the likelihood of adoption.

3. Balancing Tech-Push and Market-Pull is Key

Deep-tech ventures must navigate the tension between technological innovation (tech-push) and market demand (market-pull). The PSF process provides a structured way to balance these forces, ensuring that ventures leverage their technological capabilities while staying aligned with industry needs. This iterative approach reduces commercial risk by preventing ventures from developing solutions in search of a problem.

4. Scalability and Flexibility Enhance Adoption

While the PSF process was refined within Docklab's focus on supply chain optimisation, it was intentionally designed for broader applicability. Its iterative and modular structure enables adaptation across various industries and organisational contexts. By customising the process to specific market complexities and stakeholder dynamics, deep-tech ventures can apply it to their unique commercialisation challenges.

These insights collectively highlight how the PSF process helps deep-tech ventures move from exploratory innovation to market-aligned solutions. By providing structured tools and frameworks, this research contributes to a deeper understanding of how emerging technologies can transition from uncertain applications to commercial viability. The next section examines how these insights directly address the study's research questions and contribute to the broader objective of deep-tech commercialisation.

8.2 Answering the Research Questions

This section synthesises key findings from the study to provide concise answeres to the research questions.

Research Question (RQ):

How can deep-tech ventures solve the "solution looking for a problem" dilemma?

Deep-tech ventures can overcome this challenge by adopting the Problem-Solution Fit (PSF) process, a structured framework that aligns technological capabilities with validated market needs. The process leverages early-stage stakeholder engagement, the Reverse Hackathon as co-creation method, and iterative problem prioritisation to uncover actionable problem areas. By validating these areas before committing resources to product development, ventures can reduce the risk of market misalignment and improve their chances of commercial success.

Sub-Question 1 (SQ1)

Why do deep-tech ventures often struggle to identify relevant problem areas for achieving PSF, and what insights can literature provide on overcoming these challenges?

Deep-tech ventures often face barriers such as unclear market needs, fragmented stakeholder ecosystems, and misalignment between technical capabilities and real-world demand. Existing frameworks like Lean Startup and Design Thinking offer valuable insights but assume a predefined understanding of market needs, which is often absent in tech-push scenarios. Literature highlights key strategies to address these gaps:

- Customer-centric approaches (*Jobs to be Done, Christensen, 2007*) help define problem areas based on real industry challenges
- Standardised data-sharing protocols (*Besen & Farrell, 1994*) improve stakeholder collaboration and trust
- Balanced tech-push and market-pull strategies (*Gans & Stern, 2002)* ensure adaptability in dynamic markets.

However, a structured process for early-stage problem identification and validation in deep-tech remains a critical gap, which the PSF process seeks to address.

Sub-Question 2 (SQ2)

How can insights from a single case study in the supply chain sector inform the development of a process for identifying and prioritising high-impact problem areas in deep-tech ventures?

The Docklab case study provided actionable insights into the importance of iterative validation, stakeholder engagement, and targeted problem discovery. The use of the Reverse Hackathon demonstrated its effectiveness in incorporating external and diverse stakeholder perspectives and uncovering actionable problem areas. The case study also emphasised the need for sector-specific value propositions and clear criteria for prioritisation, reinforcing the importance of adaptability and focus in the PSF process, ensuring its relevance beyond supply chains.

Sub-Question 3 (SQ3)

What criteria should be applied to prioritise and validate problem areas, ensuring they are actionable, solvable, and aligned with market needs?

The research identified four key problem prioritisation criteria:

1. Actionability: The problem must be clearly defined, feasible to address, and align with the venture's technological capabilities (e.g. port congestion forecasting).

2. Stakeholder Alignment: The problem should align with the interests of key stakeholders, including regulators, industry partners, and end-users. Early collaboration enables a shared ownership perspective.

3. Scalability: The problem should allow for incremental growth, enabling ventures to start with small-scale pilots before expanding into broader applications.

4. Market Relevance: Priority should be given to problems that address critical industry challenges such as regulatory compliance, operational efficiency, or sustainability, ensuring stronger market traction.

By applying these criteria, ventures can prioritise high-impact opportunities and allocate resources efficiently.

Sub-Question 4 (SQ4)

What does a Problem-Solution Fit (PSF) process look like that supports deep-tech ventures in aligning their capabilities with validated problem areas?

The PSF process consists of three iterative phases:

1. Exploration: Conducting stakeholder mapping, exploratory calls, and assumption mapping to identify potential problem areas.
2. Validation: Using the Reverse Hackathon method to refine and prioritise the most pressing challenges.
3. Decision: Applying prioritisation criteria to determine whether to proceed, privot, or pause, ensuring informed resource allocation.

This structured process helps deep-tech ventures move from exploratory innovation to market-aligned solutions by ensuring that technological advancements address real, solvable problems.

These findings demonstrate how the PSF process provides a systematic and adaptable appraoch for deep-tech ventures to transition from uncertain applications to commercially viable solutions. The next section reflects on the broader implications of this research.

8.3 Final Remarks

This research advances the understanding of deep-tech commercialisation, addressing key challenges unique to tech-push contexts. Its significance lies in the development of the Problem-Solution Fit (PSF) process, which emphasises early problem validation and proactive stakeholder engagement as essential steps in commercialisation.

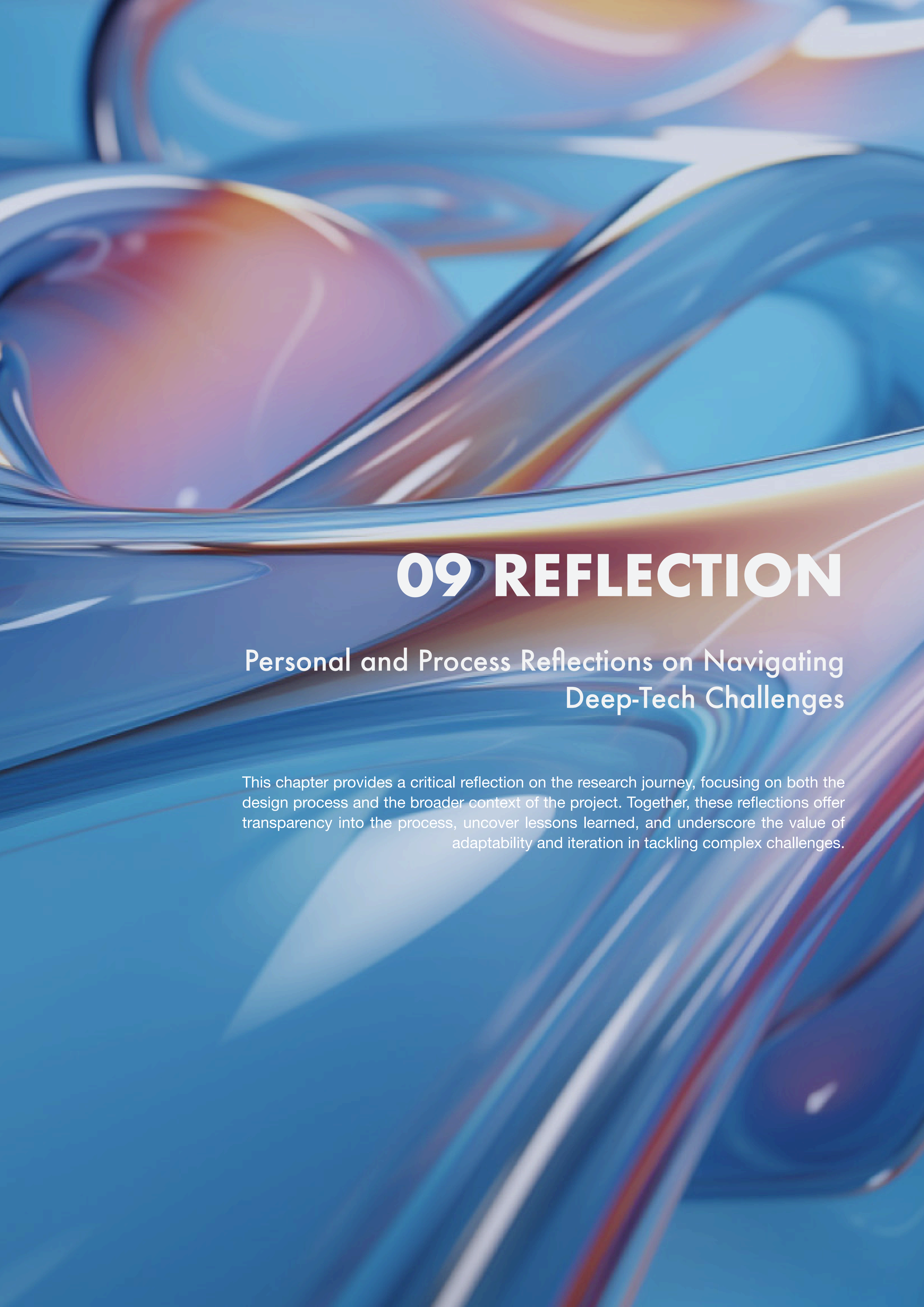
The study bridges gaps in extant literature by integrating co-creation tools like the Reverse Hackathon into a structured, scalable process. This contribution offers actionable insights for both researchers and practitioners, reinforcing the importance of finding problem-solution fit for sustainable commercialisation. The scalability of the PSF process opens new directions for future research and industry applications, including (1) testing its applicability in other deep-tech domains, (2) enabling industry-wide standards for early-stage feasibility assessment, and (3) encouraging systematic problem identification to improve resource allocation in innovation ventures.

Beyond individual ventures, these findings have broader implications for innovation ecosystems. Policymakers, industry facilitators, and venture builders can leverage this process to enable collaboration, reduce commercialisation barriers, and support sustainable innovation.
To make these insights more accessible, this research includes practical guides for ventures navigating the “solution looking for a problem” dilemma and implementing the Reverse Hackathon method. These resources, available in Appendix E, provide:

- **A one-pager (30-second read)** summarising key steps for aligning technology with market needs
- **A three-pager (5-minute read)** offering a structured guide to executing a Reverse Hackathon and applying the PSF process.

By prioritising proactive stakeholder alignment, iterative refinement, and market relevance, the PSF process strengthens the connection between emerging technologies and actionable solutions. This approach not only advances commercialisation strategies but also contributes to broader societal challenges such as sustainability and digital transformation.

This study lays the foundation for **reshaping how deep-tech ventures approach market alignment**, paving the way for further exploration. The next chapter presents personal reflections on the research process and outcomes, discussing challenges faced, lessons learned, and the broader impact of this work.



09 REFLECTION

Personal and Process Reflections on Navigating Deep-Tech Challenges

This chapter provides a critical reflection on the research journey, focusing on both the design process and the broader context of the project. Together, these reflections offer transparency into the process, uncover lessons learned, and underscore the value of adaptability and iteration in tackling complex challenges.

9.1 Reflecting on the Research Process

Reflecting on the research journey, several key challenges and learning points shaped this thesis, offering valuable insights into the complexities of deep-tech commercialisation. Below, I outline the critical lessons learned and their influence on the research process.

Adapting Objectives: From Finding a Client to Developing a Framework

One of the most significant turning points in the research process was shifting my objective from finding a direct client for NexTwin to creating a replicable PSF process. Early efforts to identify a client revealed the lack of an immediate market fit, reframing the research focus. This realisation underscored the importance of designing a process that could address the "solution looking for a problem" dilemma more broadly, beyond a single technology or industry context. This pivot not only broadened the research's applicability but also highlighted the value of embracing ambiguity as an inherent part of the deep-tech journey.

Organising the Reverse Hackathon

Designing and facilitating the Reverse Hackathon proved to be a critical step in validating the PSF process. Challenges like balancing diverse stakeholder perspectives and managing group dynamics underscored the importance of clear preparation and adaptable facilitation. Refinements, such as clarifying participant roles and simplifying prioritisation criteria, strengthened the method's effectiveness. The dual-layered approach of individual reflection followed by structured group discussions ensured that personal insights informed co-created problem definitions, aligning with stakeholder needs.

Addressing Core Barriers

The research process revealed insights into how the PSF process could address three critical barriers in deep-tech commercialisation: stakeholder engagement, integration challenges, and strategic tensions between market-pull and tech-push.
Tools like assumption mapping and role-reversal ideation enbaled stakeholder alignment, while interdisciplinary design (drawing on sociology and cognitive science) supported collaborative problem discovery. By prioritising validated, actionable problem areas, the process provided a framework for bridging market and technological needs.

Lessons in Adaptability

A recurring theme throughout the research process was the importance of adaptability. While setbacks, such as the lack of a direct client for NexTwin, initially seemed discouraging, they ultimately enriched the process by exposing deeper challenges. These experiences taught me to view unexpected outcomes not as a failure but as opportunities to refine the process and generate broader insights.

Through iterative testing and stakeholder engagement, I learned to balance theoretical rigour with practical applicability, ensuring the PSF process remained relevant across different contexts. This iterative learning approach strengthened the research and underscored the value of process-oriented methodologies in tackling complex challenges.

Key Takeaways

The research process underscored the importance of adaptability, collaboration, and iterative refinement in designing methodologies for deep-tech ventures. By focusing on stakeholder engagement and interdisciplinary insights, I was able to create a replicable process that addresses complex barriers of early-stage commercialisation.

9.2 Reflecting on the Project

This project provided valuable insights into the broader challenges of deep-tech commercialisation, revealing the connection between organisational dynamics, systemic barriers, and personal growth. Unlike the design process, which focused on creating and validating the PSF methodology, the project as a whole required navigating Docklab's specific context while addressing deep-tech ventures' unique obstacles.

Organisational Influence

Working within Docklab highlighted how organisational structured and cultures directly affect innovation outcomes. Challenges such as broad value propositions, reactive client outreach, and unclear strategic focus shaped the project's direction. Even with three client leads generated through the Reverse Hackathon, Docklab's hesitation to pursue these opportunities revealed a deeper need for alignment between ambitions and execution capabilities. This experience underscored the importance of internal clarity and commitment in supporting commercialisation efforts.

Strategic and Systemic Insights

The project demonstrated that achieving Problem-Solution Fit is only one part of the broader commercialisation puzzle. Deep-tech ventures face barriers that extended beyond individual frameworks (stakeholder engagement, integration challenges, and strategic tensions). While the PSF process addressed key aspects of these barriers, the inability to resolve organisational inertia reinforced the limitations of frameworks when broader fundamental issues are at play.

Personal Growth

On a personal level, the project was a journey of resilience and adaptability. Shifting focus from securing a pilot client for NexTwin to refining a replicable methodology was a turning point. While initially frustrating, this shift allowed me to embrace the value of long-term, strategic contributions over immediate results. It taught me that research outcomes are not solely defined by tangible deliverables but by the frameworks, insights, and conversations that they inspire.

Looking Ahead

Reflecting on the project as a whole, it became clear that the PSF process is a starting point for addressing systemic challenges in deep-tech commercialisation. The insights generated through this work extend beyond Docklab, offering lessons for other ventures navigating similar complexities. For me personally, the project emphasised the value of proactive engagement; actively seeking stakeholder input and addressing challenges early proved essential in navigating the complexities of deep-tech commercialisation.

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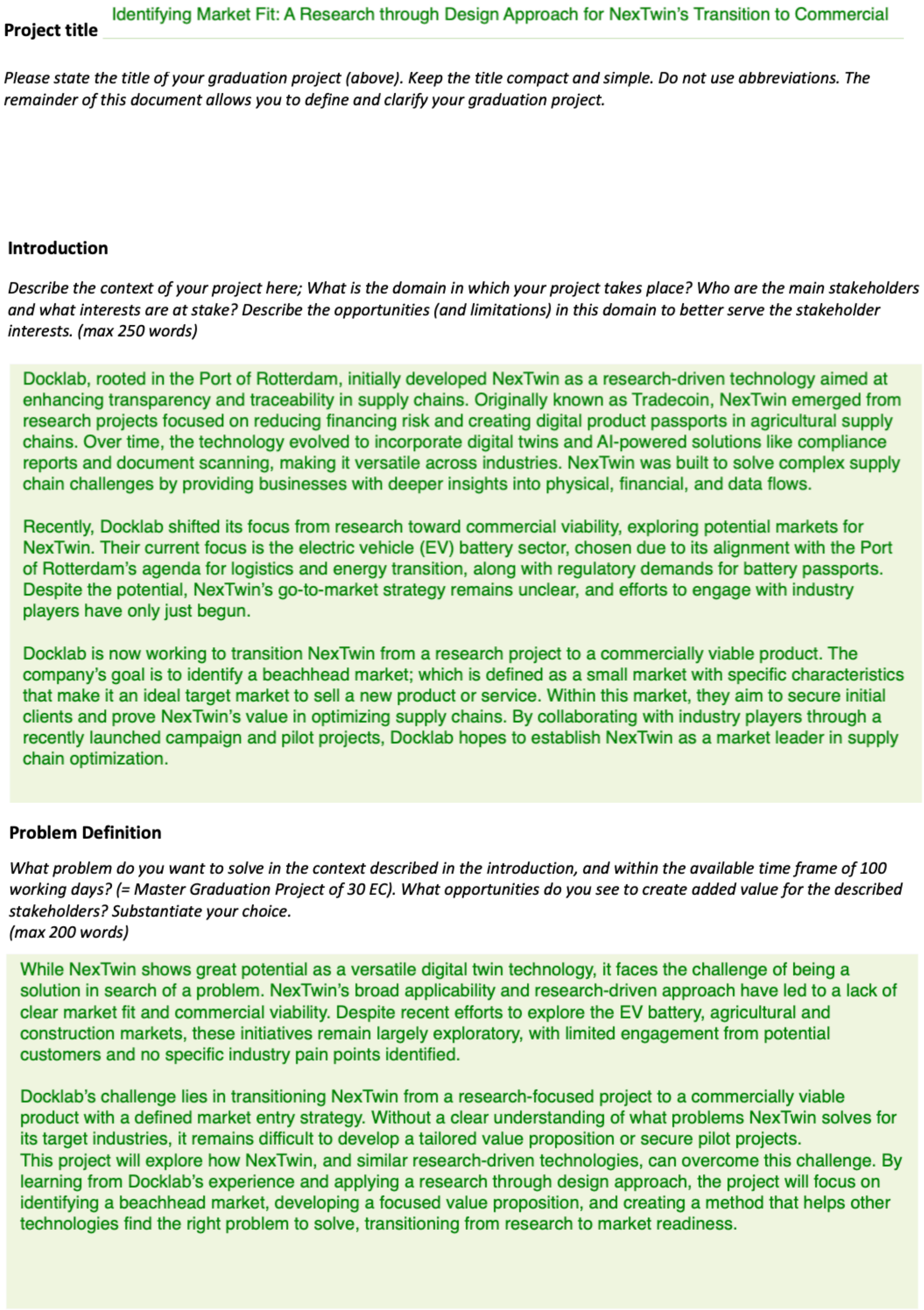
Appendix

A. Project Brief



Project title Identifying Market Fit: A Research through Design Approach for NexTwin's Transition to Commercial

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Docklab, rooted in the Port of Rotterdam, initially developed NexTwin as a research-driven technology aimed at enhancing transparency and traceability in supply chains. Originally known as Tradecoin, NexTwin emerged from research projects focused on reducing financing risk and creating digital product passports in agricultural supply chains. Over time, the technology evolved to incorporate digital twins and AI-powered solutions like compliance reports and document scanning, making it versatile across industries. NexTwin was built to solve complex supply chain challenges by providing businesses with deeper insights into physical, financial, and data flows.

Recently, Docklab shifted its focus from research toward commercial viability, exploring potential markets for NexTwin. Their current focus is the electric vehicle (EV) battery sector, chosen due to its alignment with the Port of Rotterdam's agenda for logistics and energy transition, along with regulatory demands for battery passports. Despite the potential, NexTwin's go-to-market strategy remains unclear, and efforts to engage with industry players have only just begun.

Docklab is now working to transition NexTwin from a research project to a commercially viable product. The company's goal is to identify a beachhead market; which is defined as a small market with specific characteristics that make it an ideal target market to sell a new product or service. Within this market, they aim to secure initial clients and prove NexTwin's value in optimizing supply chains. By collaborating with industry players through a recently launched campaign and pilot projects, Docklab hopes to establish NexTwin as a market leader in supply chain optimization.

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

While NexTwin shows great potential as a versatile digital twin technology, it faces the challenge of being a solution in search of a problem. NexTwin's broad applicability and research-driven approach have led to a lack of clear market fit and commercial viability. Despite recent efforts to explore the EV battery, agricultural and construction markets, these initiatives remain largely exploratory, with limited engagement from potential customers and no specific industry pain points identified.

Docklab's challenge lies in transitioning NexTwin from a research-focused project to a commercially viable product with a defined market entry strategy. Without a clear understanding of what problems NexTwin solves for its target industries, it remains difficult to develop a tailored value proposition or secure pilot projects.
This project will explore how NexTwin, and similar research-driven technologies, can overcome this challenge. By learning from Docklab's experience and applying a research through design approach, the project will focus on identifying a beachhead market, developing a focused value proposition, and creating a method that helps other technologies find the right problem to solve, transitioning from research to market readiness.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design a concept product service system (PSS) to transition Docklab's NexTwin technology from a research-driven solution to a commercially viable product. This system should identify a beachhead market and create a tailored value proposition for NexTwin within the digital twin landscape. The project will develop a structured

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

This project will use a research through design approach to explore how NexTwin can transition from research to commercial viability. The first phase will involve a literature review on commercializing research-driven technologies and analyzing Docklab's previous and current customer engagement efforts in markets like biofuels and construction.

Next, I will conduct customer engagement to gather insights on industry pain points, followed by developing and testing a concept product service system (PSS) tailored to a beachhead market. This iterative process will focus on refining Nextwin's value proposition based on feedback.

Design methods will include the Double Diamond process, where insights from discovery and definition phases will guide the development and delivery of the final PSS. This structured approach will help Docklab identify a viable market and create a go-to-market strategy for NexTwin.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting 09/09/2024

Mid-term evaluation 07/11/2024

Green light meeting 10/01/2025

Graduation ceremony 07 Feb 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I am excited to work on the NexTwin project for my graduation as it provides the chance to blend my strategic design skills with a research-driven challenge. This project allows me to apply a research through design approach to a real-world problem, transitioning a solution in search of a problem into a commercially viable product. I am particularly motivated by the opportunity to define market positioning for NexTwin, engage with potential customers, and develop a concept PSS that aligns with market needs. I find it rewarding to bridge the gap between research and commercial viability, and feel like I could really make a change here by transforming insights into actionable business strategies.

I am eager to further develop my skills in customer engagement, B2B go-to-market strategy design, and market fit analysis, especially because Docklab can't be the first with this particular problem. A personal ambition is to refine and validate a structured method that could guide similar research-driven technologies to find their market fit, ultimately benefiting both Docklab and the wider digital twin landscape.

B. Interview Guide

This appendix provides an example of an interview guide used during the research. While each interview was tailored to the interviewee to ensure more relevant and insightful responses, this guide illustrates the structure and types of questions asked. Before each interview, a brief contextual introduction was given to provide background on the research and its objectives, setting the stage for the discussion.

Customer needs & pain points (context: Maersk's Expertise in Supply Chain Management)
1. Maersk has a strong track record in supply chain management, including resilience and operational efficiency. Could you describe a recent situation where a major supply chain disruption challenged your operations?
Goal: to understand the key pain points that blockchain or digital twin technologies could address

2. In industries with global supply chains, transparency and real-time data flow are critical. How do you currently address inefficiencies or delays in your supply chain operations?
Goal: to uncover operational challenges that blockchain could potentially solve

3. With increasing complexity in supply chains, what solutions are you looking for to enhance visibility and decision-making across different stakeholders?
Goal: Learn about unmet needs and gaps in current systems

Blockchain project experience (context: their previous Blockchain initiative with IBM)
4. I understand Maersk previously worked on a blockchain project called TradeLens for supply chain management, but it was discontinued two years ago. Could you share what the initial goals were for this project and the reasons behind its discontinuation?
Goal: explore lessons learned from the project, its pain points, roadblocks for future

5. In hindsight, are there specific challenges or industry factors that made blockchain difficult to implement in the context of supply chains? Do you think these challenges have evolved?
Goal: insight into challenges they faced with blockchain & whether they see a future for it in similar applications

Perceptions of NexTwin & digital twins (context: exploring NexTwin's relevance)
6. Maersk works in a dynamic global environment. Have you explored digital twin technologies before? What are your impressions of them, especially when it comes to enhancing resilience and operational visibility?
Goal: explore familiarity with digital twins

7. How do you see digital twin technology aligning with Maersk's goals for building a more resilient and transparent supply chain? What key problems would you expect it to address?
Goal: understand whether digital twins solve real challenges for Maersk

8. Based on your understanding, do you think NexTwin's value proposition, which is enhanced transparency and traceability of supply chains, addresses a significant pain point for Maersk? If not, where does it fall short?
Goal: identify gaps in NexTwin's value proposition and potential misalignment with customer needs

Commercial viability & adoption (context: barriers and opportunities for NexTwin)
9. When considering new technologies for the supply chain, what factors do you prioritize most (think of cost reduction, operational efficiency, scalability)?
Goal: identify key decision-making criteria for adoption solutions like NexTwin

10. What would be your primary concerns or challenges with implementing digital twin technologies within Maersk's global operations?
Goal: understand possible barriers to adoption, like costs, integration issues, return on investment

11. If NexTwin could demonstrate significant improvements in areas like predictive maintenance or real-time tracking, what would make Maersk more willing to pilot or invest in such technology?
Goal: conditions under which Maersk would be open to partner or pilot

C. Data Analysis Results

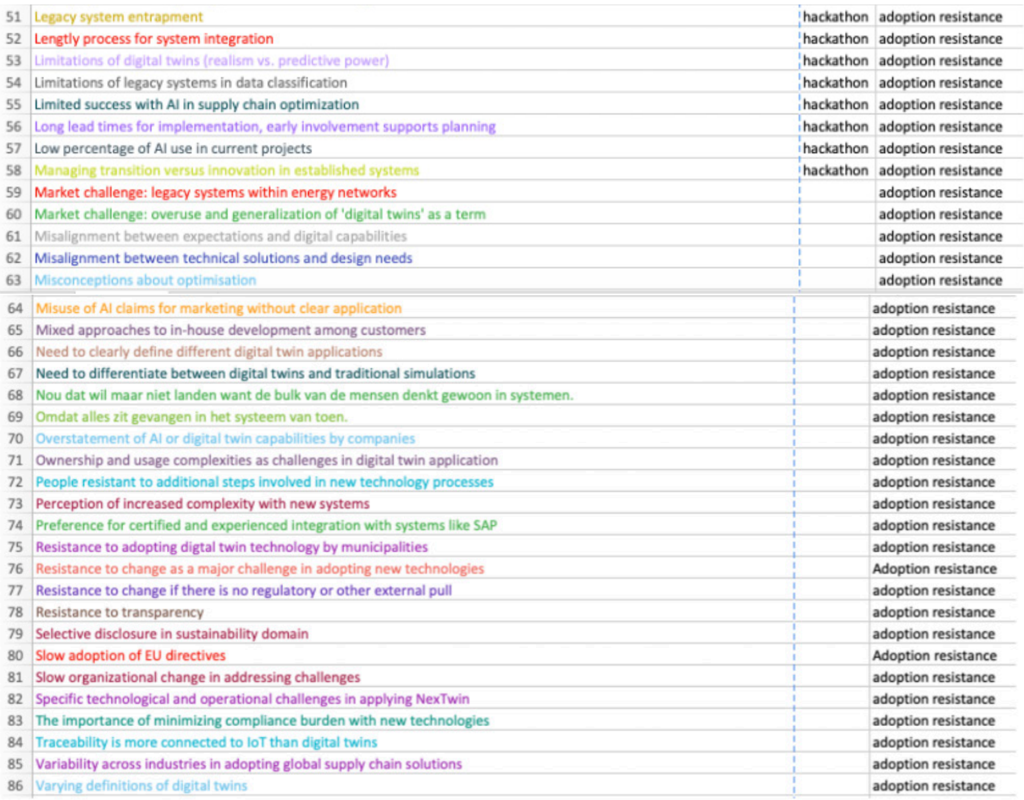
This appendix presents the findings from the data analysis, categorising insights gathered from interviews and the Reverse Hackathon. The analysis identified 20 key categories, each with corresponding codes and a detailed summary of insights. Additionally, the dataset distinguishes whether insights originated from the Reverse Hackathon or other research activities, providing context on how different methods contributed to the findings. By structuring the results this way, this appendix offers a transparent view of how themes emerged from the data and how they informed the development of the Problem-Solution Fit (PSF) process.

C1. Market Challenges

Adoption Resistance

Key insights: Resistance to adopting digital twin technologies is rooted in reliance on legacy systems, unclear business models, and organisational inertia. Companies often struggle to integrate digital twins into ongoing operations, particularly when outdated infrastructure dominates. Market fragmentation and constant customisation requirements further discourage adoption. Additionally, resistance to change is amplified by a lack of understanding of the technology's value, leading to scepticism among decision-makers and operational teams.

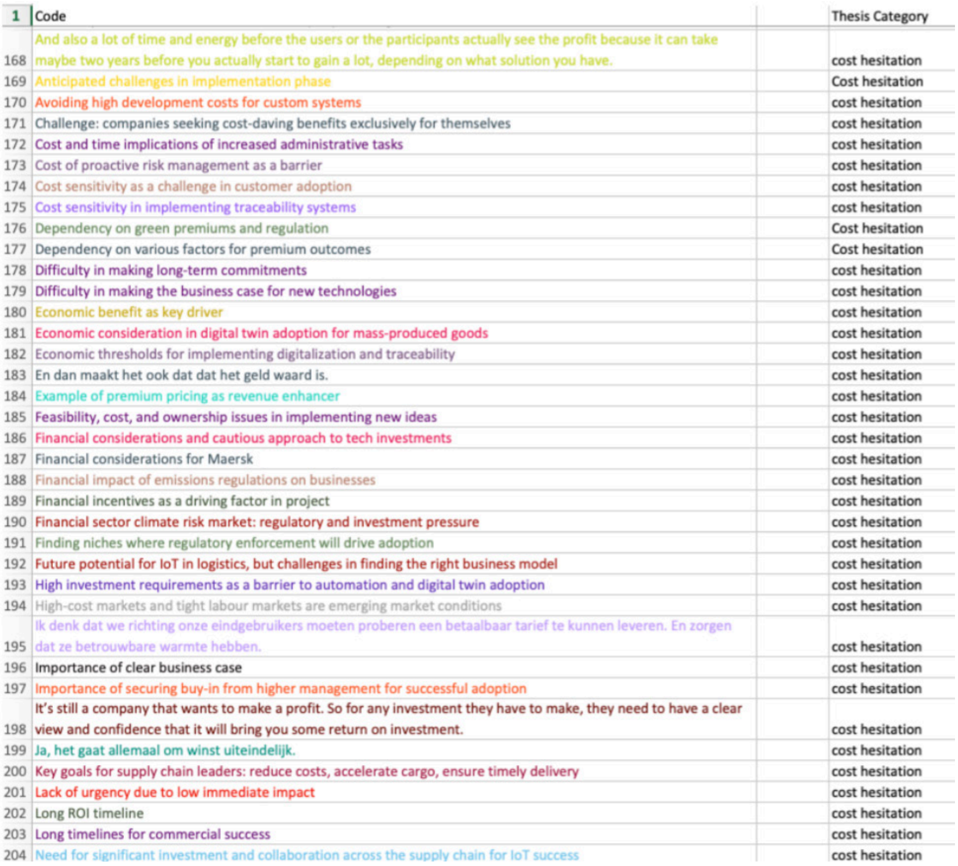
1	Code		Thesis Category
2	Absence of a clear business model as a barrier for IoT adoption		Adoption resistance
3	Adoption driven by downstream players		Adoption resistance
4	And unless you do the twin fairly good, the existing solutions are good enough. And they don't warrant an investment, a larger investment.		Adoption resistance
5	Barriers to technology adoption in lower-tier supply chain actors		adoption resistance
6	Both high-tech and retail companies consider in-house tool development		Adoption resistance
7	Broader, non-tech customer base challenges communication		Adoption resistance
8	Budget allocation for the research phase		adoption resistance
9	Challenge of low-tech suppliers in implementing advanced technology		adoption resistance
10	Challenge: integration with legacy networks is a significant hurdle		adoption resistance
11	Challenge: interpreting legacy systems to integrate new technology		adoption resistance
12	Challenge: low digitalisation levels among supply chain partners		adoption resistance
13	Challenges in determining entitlement to technology		adoption resistance
14	Challenges in integrating tech solutions into existing company infrastructure		adoption resistance
15	Challenges with IoT adoption in supply chains (collaboration and usage)		adoption resistance
16	Clients want more certainty than just a promise of integration	hackathon	adoption resistance
17	Companies delay adoption until penalties		Adoption resistance
18	Complexity in classifying real-world incidents in legacy systems		adoption resistance
19	Cultural resistance to change among traditional technologists		adoption resistance
20	Cultural unawareness of modern data practices		adoption resistance
21	Current state of ERP systems in transition and lacking sophistication		adoption resistance
22	Current strategy for resolving work challenges is using powerpoint for communication		adoption resistance
23	Difficulty changing traditional logistics		adoption resistance
24	Digital solution adoption is still in development		adoption resistance
25	Digital twin association with engineering, domain-specific perception	hackathon	adoption resistance
26	Digital twin is a buzz word		adoption resistance
27	Digital twin technology as a niche term		adoption resistance
28	Digital twins as a broad concept with varying definitions	hackathon	adoption resistance
29	Digital twins as a flexible concept with various interpretations		adoption resistance
30	Dus dat is in die zin best een complexe transitie.		adoption resistance
31	Emotional or political baggage can overshadow rational arguments		adoption resistance
32	Emphasis on change management in adopting new technologies		adoption resistance
33	Existing solutions are good enough		adoption resistance
34	Focus on internal optimizations may distance focus from end-users		adoption resistance
35	For scenario analysis and long-term forecasting, you don't need real-time data		adoption resistance
36	High stakes in technical innovation and system overhaul	hackathon	adoption resistance
37	However, it's not a fortune teller, it cannot say 'hey these disruptions will definitely lead to these directions'. The result from the digital twin is not exactly the reality.		adoption resistance
38	ik denk dat Digital Twin ook een paraplu term is.		adoption resistance
39	Implementation time as a barrier		adoption resistance
40	Infrastructure challenge: aging underground systems		adoption resistance
41	Integration as the biggest challenge	hackathon	adoption resistance
42	Integration challenges are more operational	hackathon	adoption resistance
43	Integration should not be difficult	hackathon	adoption resistance
44	Integration with multiple ERP systems and transport management systems is more complex	hackathon	adoption resistance
45	Issue: even simple compenents like sensors present integration challenges due to data diversity	hackathon	adoption resistance
46	Je ziet dat de consument natuurlijk ook een heel stuk mondiger is geworden van wat de consument zelf wil.	hackathon	adoption resistance
47	Lack of advanced technology in many so-called AI tools	hackathon	adoption resistance
48	Lack of collaboration and unclear ROI as barriers to IoT adoption	hackathon	adoption resistance
49	Lack of innovation in the energy sector compared to other sectors	hackathon	adoption resistance
50	Legacy system challenges in public sector data management	hackathon	adoption resistance



51	Legacy system entrapment	hackathon	adoption resistance
52	Lengtly process for system integration	hackathon	adoption resistance
53	Limitations of digital twins (realism vs. predictive power)	hackathon	adoption resistance
54	Limitations of legacy systems in data classification	hackathon	adoption resistance
55	Limited success with AI in supply chain optimization	hackathon	adoption resistance
56	Long lead times for implementation, early involvement supports planning	hackathon	adoption resistance
57	Low percentage of AI use in current projects	hackathon	adoption resistance
58	Managing transition versus innovation in established systems	hackathon	adoption resistance
59	Market challenge: legacy systems within energy networks		adoption resistance
60	Market challenge: overuse and generalization of 'digital twins' as a term		adoption resistance
61	Misalignment between expectations and digital capabilities		adoption resistance
62	Misalignment between technical solutions and design needs		adoption resistance
63	Misconceptions about optimisation		adoption resistance
64	Misuse of AI claims for marketing without clear application		adoption resistance
65	Mixed approaches to in-house development among customers		adoption resistance
66	Need to clearly define different digital twin applications		adoption resistance
67	Need to differentiate between digital twins and traditional simulations		adoption resistance
68	Nou dat wil maar niet landen want de bulk van de mensen denkt gewoon in systemen.		adoption resistance
69	Omdat alles zit gevangen in het systeem van toen.		adoption resistance
70	Overstatement of AI or digital twin capabilities by companies		adoption resistance
71	Ownership and usage complexities as challenges in digital twin application		adoption resistance
72	People resistant to additional steps involved in new technology processes		adoption resistance
73	Perception of increased complexity with new systems		adoption resistance
74	Preference for certified and experienced integration with systems like SAP		adoption resistance
75	Resistance to adopting digtal twin technology by municipalities		adoption resistance
76	Resistance to change as a major challenge in adopting new technologies		Adoption resistance
77	Resistance to change if there is no regulatory or other external pull		adoption resistance
78	Resistance to transparency		adoption resistance
79	Selective disclosure in sustainability domain		adoption resistance
80	Slow adoption of EU directives		Adoption resistance
81	Slow organizational change in addressing challenges		adoption resistance
82	Specific technological and operational challenges in applying NexTwin		adoption resistance
83	The importance of minimizing compliance burden with new technologies		adoption resistance
84	Traceability is more connected to IoT than digital twins		adoption resistance
85	Variability across industries in adopting global supply chain solutions		adoption resistance
86	Varying definitions of digital twins		adoption resistance

Cost Hesitation

Key insights: The high costs of developing, customising, and implementing digital twin solutions create significant hesitation among companies. Many organisations lack the readiness to justify infrastructure investment without a clear return on investment (ROI). Pilot projects are often viewed as useful experiments but fail to transition into broader adoption due to stakeholders' reluctance to invest further. This hesitation is amplified by short-term financial pressures, unclear long-term benefits, and weak internal business cases, which prevent scaling beyond initial stages.



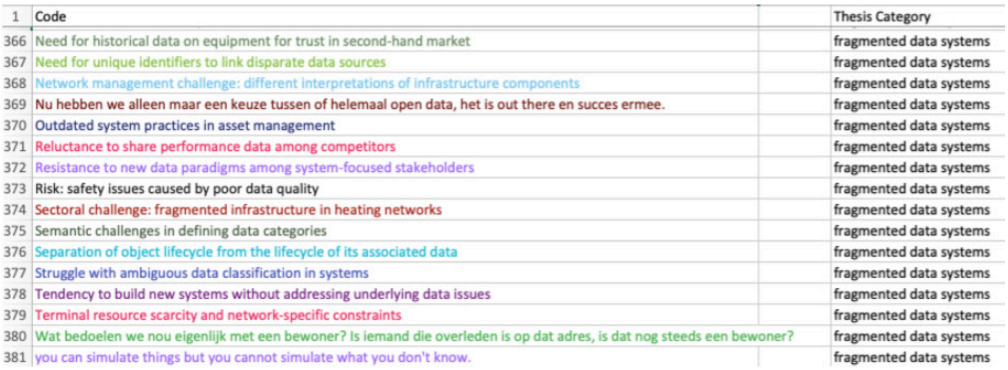
1	Code		Thesis Category
168	And also a lot of time and energy before the users or the participants actually see the profit because it can take maybe two years before you actually start to gain a lot, depending on what solution you have.		cost hesitation
169	Anticipated challenges in implementation phase		Cost hesitation
170	Avoiding high development costs for custom systems		cost hesitation
171	Challenge: companies seeking cost-daving benefits exclusively for themselves		cost hesitation
172	Cost and time implications of increased administrative tasks		cost hesitation
173	Cost of proactive risk management as a barrier		cost hesitation
174	Cost sensitivity as a challenge in customer adoption		cost hesitation
175	Cost sensitivity in implementing traceability systems		cost hesitation
176	Dependency on green premiums and regulation		Cost hesitation
177	Dependency on various factors for premium outcomes		Cost hesitation
178	Difficulty in making long-term commitments		cost hesitation
179	Difficulty in making the business case for new technologies		cost hesitation
180	Economic benefit as key driver		cost hesitation
181	Economic consideration in digital twin adoption for mass-produced goods		cost hesitation
182	Economic thresholds for implementing digitalization and traceability		cost hesitation
183	En dan maakt het ook dat dat het geld waard is.		cost hesitation
184	Example of premium pricing as revenue enhancer		cost hesitation
185	Feasibility, cost, and ownership issues in implementing new ideas		cost hesitation
186	Financial considerations and cautious approach to tech investments		cost hesitation
187	Financial considerations for Maersk		cost hesitation
188	Financial impact of emissions regulations on businesses		cost hesitation
189	Financial incentives as a driving factor in project		cost hesitation
190	Financial sector climate risk market: regulatory and investment pressure		cost hesitation
191	Finding niches where regulatory enforcement will drive adoption		cost hesitation
192	Future potential for IoT in logistics, but challenges in finding the right business model		cost hesitation
193	High investment requirements as a barrier to automation and digital twin adoption		cost hesitation
194	High-cost markets and tight labour markets are emerging market conditions		cost hesitation
195	Ik denk dat we richting onze eindgebruikers moeten proberen een betaalbaar tarief te kunnen leveren. En zorgen dat ze betrouwbare warmte hebben.		cost hesitation
196	Importance of clear business case		cost hesitation
197	Importance of securing buy-in from higher management for successful adoption		cost hesitation
198	It's still a company that wants to make a profit. So for any investment they have to make, they need to have a clear view and confidence that it will bring you some return on investment.		cost hesitation
199	Ja, het gaat allemaal om winst uiteindelijk.		cost hesitation
200	Key goals for supply chain leaders: reduce costs, accelerate cargo, ensure timely delivery		cost hesitation
201	Lack of urgency due to low immediate impact		cost hesitation
202	Long ROI timeline		cost hesitation
203	Long timelines for commercial success		cost hesitation
204	Need for significant investment and collaboration across the supply chain for IoT success		cost hesitation

205	Post-pilot investment hesitation		cost hesitation
206	Price and business case challenges for tech adoption		cost hesitation
207	Prioritization of revenue-generating technologies that solve customer pain points		cost hesitation
208	Profit remains the primary driver for companies		cost hesitation
209	Revenue-driven adoption		cost hesitation
210	Short-term financial costs hinder adoption		cost hesitation
211	Supply chain decision-making challenges in crisis (inventory, costs, impact)		cost hesitation
212	Supply chain manager: avoiding fines and time savings		cost hesitation
213	Supply chain manager: improved planning and cost reduction/revenue enhancing, and a solution for regulatory compliance		cost hesitation
214	Time and energy investment before seeing benefits		cost hesitation
215	Waarom zou je dat gaan doen? De klant zegt dan van, volgens mij geld.		cost hesitation

Fragmented Data Systems

Key insights: Fragmented data sources, poor data quality, and inconsistent formats across supply chains pose critical challenges to digital twin adoption. Companies face bottlenecks in achieving data interoperability, with competitive sensitivities further restricting data-sharing practices. Regulatory gaps around standardisation intensify these challenges, as inconsistent data management practices lead to inefficiencies and reduced collaboration. Moreover, the inability to track financial, goods, and data flows seamlessly underscores the need for stronger data governance and regulatory enforcement.

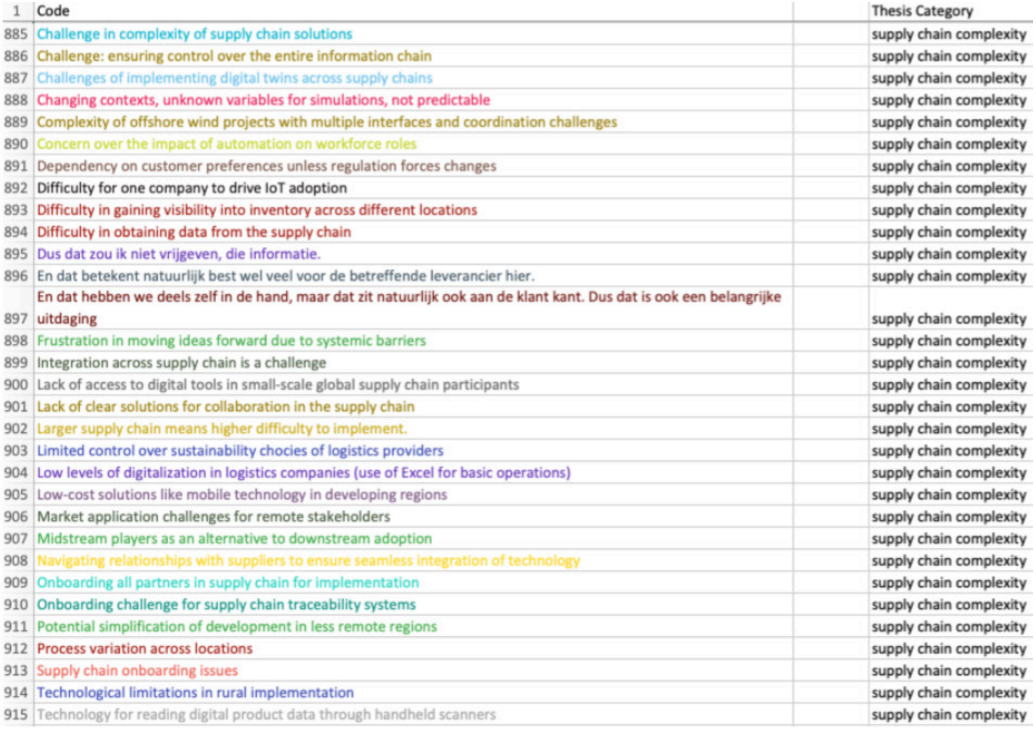
1	Code		Thesis Category
306	Stable, physical nature of assets in the energy sector (e.g. transformers, cables)		fragmeneted data systems
307	Barrier: innovation is hindered due to legacy system integration issues		fragmented data systems
308	But that is really important if you want to have data from different sources.		fragmented data systems
309	But that's accuracy is again a question.		Fragmented data systems
310	Categorization challenges in associating data with different identities		Fragmented data systems
311	Challenge in assigning identity to data clusters		fragmented data systems
312	Challenge of ensuring meaningful data input		fragmented data systems
313	Challenge of handling large data volumes		fragmented data systems
314	Challenge: automation hindered by poor data quality		fragmented data systems
315	Challenge: binary choice between open and closed data systems		fragmented data systems
316	Challenge: existing technology is outdated, limiting innovation		fragmented data systems
317	Challenge: inconsistent data formats across suppliers		fragmented data systems
318	Challenge: information flow and data needs across the energy sector		fragmented data systems
319	Challenge: integrating diverse datasets and algorithms		fragmented data systems
320	Challenge: managing and filtering data from unsuccessful innovations		fragmented data systems
321	Challenge: managing chaotic data landscapes built over long periods		fragmented data systems
322	Challenge: multiple generations of technoloy within energy networks		fragmented data systems
323	Complex, redundant system integrations creating inefficiencies		fragmented data systems
324	Concern over data accuracy in remote contexts		fragmented data systems
325	Concerns over governmental access to large data pools		fragmented data systems
326	Context-specific reasoning models for integrating data		fragmented data systems
327	Data challenge: basic infrastructure information varies depending on the role		fragmented data systems
328	Data challenge: external temperature is not an accurate measure of demand		fragmented data systems
329	Data interpretation, avoiding bias		fragmented data systems
330	Data is most of the time not enough. The context helps to see better. I think that's more or less what I thought of.		fragmented data systems
331	Data lacking contextual understanding		fragmented data systems
332	Data management for physical objects and related work processes		fragmented data systems
333	Data sharing challenges		fragmented data systems
334	data sharing willingness		fragmented data systems
335	Data transfer challenges between legacy systems		fragmented data systems
336	Data validation challenges		fragmented data systems
337	Data-driven approach to understanding relationships between parties and locations		fragmented data systems
338	Data-driven approach: historical data as the basis for predictions		fragmented data systems
339	Data-sharing reluctance due to competitive sensitivity		fragmented data systems
340	Data-sharing restrictions as a regulatory barrier		fragmented data systems
341	Discrepancy between legal frameworks and operational perceptions in data sharing		fragmented data systems
342	En daarvan wil je dus spelers, locaties, betrokken objecten, wil je deze aan elkaar kunnen relateren.		fragmented data systems
343	En dan worden ook de netwerken groter en complexer.		fragmented data systems
344	En je moet natuurlijk ook een systeem maken waarmee je dat kan.		fragmented data systems
345	Existing challenges in data management and integration		fragmented data systems
346	Failure to separate physical objects from their data		fragmented data systems
347	Ieder die een nieuwe systeem wil hebben om zelfde soort gegevens te gaan beheren, die heeft echt een heel klote vraagstuk als		fragmented data systems
348	Importance of accurate data for the value of the application		fragmented data systems
349	Importance of assumptions and past knowledge in digital twin use		fragmented data systems
350	Importance of consistent data categories and standardization		fragmented data systems
351	Importance of contextual and impact awareness for the application		fragmented data systems
352	Importance of data integration		fragmented data systems
353	Importance of documentation and evidence in digital twin adoption and value generation		fragmented data systems
354	Importance of relevant data distinctions in application and value proposition		fragmented data systems
355	in die data-deling zit ook nog best wel een uitdaging.		fragmented data systems
356	Issues with accuracy in current manual sustainability processes		fragmented data systems
357	Key challenge: data spread across multiple sources		fragmented data systems
358	Key customer need: more accurate data point beyond traditional metrics (e.g. in battery production chains where demand is influ		fragmented data systems
359	Lack of awareness and capability in the energy sector regarding data management		fragmented data systems
360	Lack of importance given to object identification by energy network operators		fragmented data systems
361	Lack of standardization in data models (market challenge)		fragmented data systems
362	Major challenge: variety of data sources across supply chains		fragmented data systems
363	Market barrier: technical debt in network operators causes difficulties for integration		fragmented data systems
364	Market challenge: processes are struggling to keep up with rapid technological change		fragmented data systems
365	Mistrust in external data systems		fragmented data systems



1	Code		Thesis Category
366	Need for historical data on equipment for trust in second-hand market		fragmented data systems
367	Need for unique identifiers to link disparate data sources		fragmented data systems
368	Network management challenge: different interpretations of infrastructure components		fragmented data systems
369	Nu hebben we alleen maar een keuze tussen of helemaal open data, het is out there en succes ermee.		fragmented data systems
370	Outdated system practices in asset management		fragmented data systems
371	Reluctance to share performance data among competitors		fragmented data systems
372	Resistance to new data paradigms among system-focused stakeholders		fragmented data systems
373	Risk: safety issues caused by poor data quality		fragmented data systems
374	Sectoral challenge: fragmented infrastructure in heating networks		fragmented data systems
375	Semantic challenges in defining data categories		fragmented data systems
376	Separation of object lifecycle from the lifecycle of its associated data		fragmented data systems
377	Struggle with ambiguous data classification in systems		fragmented data systems
378	Tendency to build new systems without addressing underlying data issues		fragmented data systems
379	Terminal resource scarcity and network-specific constraints		fragmented data systems
380	Wat bedoelen we nou eigenlijk met een bewoner? Is iemand die overleden is op dat adres, is dat nog steeds een bewoner?		fragmented data systems
381	you can simulate things but you cannot simulate what you don't know.		fragmented data systems

Supply Chain Complexity

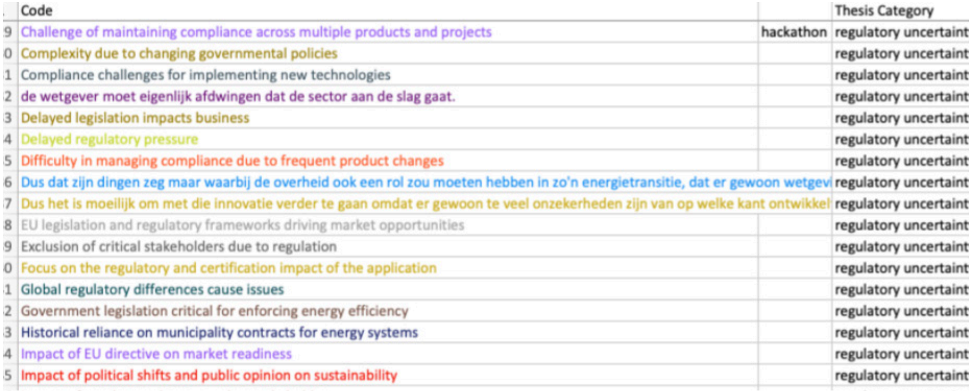
Key insights: Supply chain complexity, driven by varying levels of digitalisation, poor visibility, and geopolitical factors, presents significant barriers to digital twin adoption. Transparency and resilience are difficult to achieve due to inconsistent IoT integration, sustainability demands, and geographical disparities. Managing remote suppliers further compounds these issues, as limited data accuracy and digital engagement restrict the full benefits of digital twins in creating a cohesive supply chain.



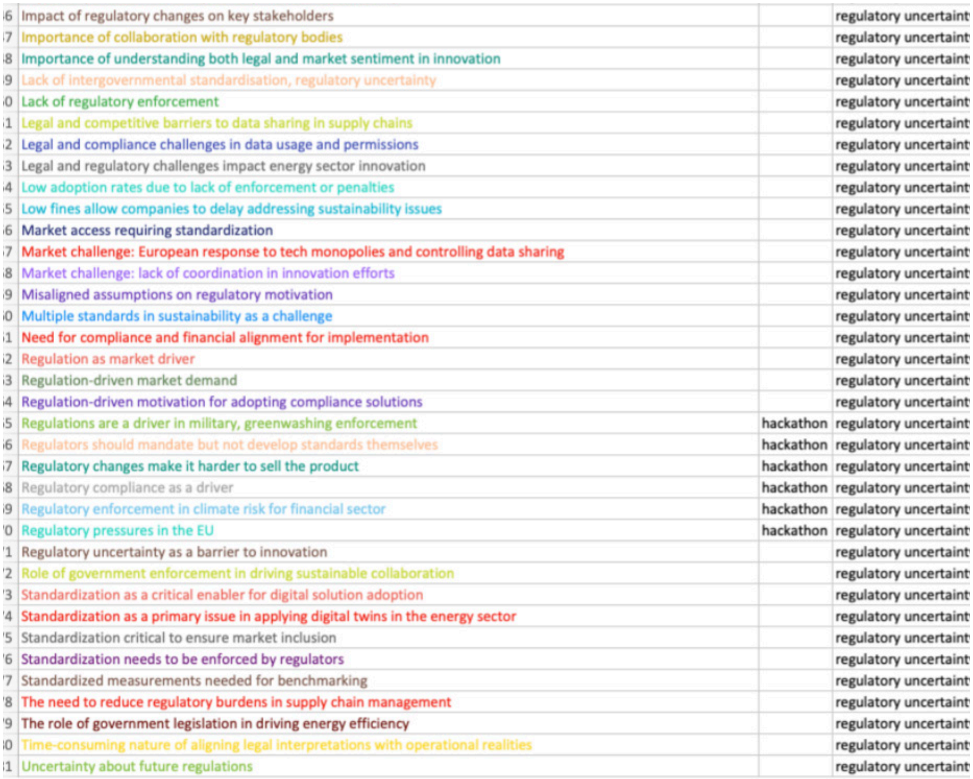
1	Code		Thesis Category
885	Challenge in complexity of supply chain solutions		supply chain complexity
886	Challenge: ensuring control over the entire information chain		supply chain complexity
887	Challenges of implementing digital twins across supply chains		supply chain complexity
888	Changing contexts, unknown variables for simulations, not predictable		supply chain complexity
889	Complexity of offshore wind projects with multiple interfaces and coordination challenges		supply chain complexity
890	Concern over the impact of automation on workforce roles		supply chain complexity
891	Dependency on customer preferences unless regulation forces changes		supply chain complexity
892	Difficulty for one company to drive IoT adoption		supply chain complexity
893	Difficulty in gaining visibility into inventory across different locations		supply chain complexity
894	Difficulty in obtaining data from the supply chain		supply chain complexity
895	Dus dat zou ik niet vrijgeven, die informatie.		supply chain complexity
896	En dat betekent natuurlijk best wel veel voor de betreffende leverancier hier.		supply chain complexity
897	En dat hebben we deels zelf in de hand, maar dat zit natuurlijk ook aan de klant kant. Dus dat is ook een belangrijke uitdaging		supply chain complexity
898	Frustration in moving ideas forward due to systemic barriers		supply chain complexity
899	Integration across supply chain is a challenge		supply chain complexity
900	Lack of access to digital tools in small-scale global supply chain participants		supply chain complexity
901	Lack of clear solutions for collaboration in the supply chain		supply chain complexity
902	Larger supply chain means higher difficulty to implement.		supply chain complexity
903	Limited control over sustainability chocies of logistics providers		supply chain complexity
904	Low levels of digitalization in logistics companies (use of Excel for basic operations)		supply chain complexity
905	Low-cost solutions like mobile technology in developing regions		supply chain complexity
906	Market application challenges for remote stakeholders		supply chain complexity
907	Midstream players as an alternative to downstream adoption		supply chain complexity
908	Navigating relationships with suppliers to ensure seamless integration of technology		supply chain complexity
909	Onboarding all partners in supply chain for implementation		supply chain complexity
910	Onboarding challenge for supply chain traceability systems		supply chain complexity
911	Potential simplification of development in less remote regions		supply chain complexity
912	Process variation across locations		supply chain complexity
913	Supply chain onboarding issues		supply chain complexity
914	Technological limitations in rural implementation		supply chain complexity
915	Technology for reading digital product data through handheld scanners		supply chain complexity

Regulatory Uncertainty

Key insights: Evolving regulatory requirements create uncertainty for companies exploring digital twin technologies, particularly in sectors like offshore energy. While sustainability and compliance pressures act as drivers for adoption, inconsistent enforcement reduces urgency. Furthermore, restrictive data-sharing regulations can exclude critical stakeholders, undermining collaboration and project outcomes. Companies struggle to navigate these shifting frameworks, resulting in delays and complications in aligning digital twins with regulatory mandates.



	Code		Thesis Category
9	Challenge of maintaining compliance across multiple products and projects	hackathon	regulatory uncertaint
0	Complexity due to changing governmental policies		regulatory uncertaint
1	Compliance challenges for implementing new technologies		regulatory uncertaint
2	de wetgever moet eigenlijk afdwingen dat de sector aan de slag gaat.		regulatory uncertaint
3	Delayed legislation impacts business		regulatory uncertaint
4	Delayed regulatory pressure		regulatory uncertaint
5	Difficulty in managing compliance due to frequent product changes		regulatory uncertaint
6	Dus dat zijn dingen zeg maar waarbij de overheid ook een rol zou moeten hebben in zo'n energietransitie, dat er gewoon wetgevi		regulatory uncertaint
7	Dus het is moeilijk om met die innovatie verder te gaan omdat er gewoon te veel onzekerheden zijn van op welke kant ontwikkel		regulatory uncertaint
8	EU legislation and regulatory frameworks driving market opportunities		regulatory uncertaint
9	Exclusion of critical stakeholders due to regulation		regulatory uncertaint
0	Focus on the regulatory and certification impact of the application		regulatory uncertaint
1	Global regulatory differences cause issues		regulatory uncertaint
2	Government legislation critical for enforcing energy efficiency		regulatory uncertaint
3	Historical reliance on municipality contracts for energy systems		regulatory uncertaint
4	Impact of EU directive on market readiness		regulatory uncertaint
5	Impact of political shifts and public opinion on sustainability		regulatory uncertaint



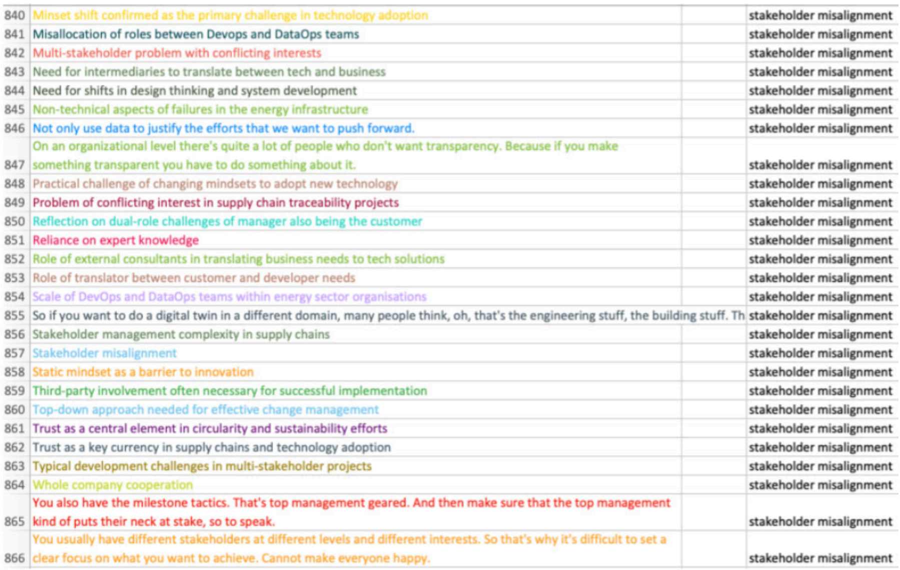
6	Impact of regulatory changes on key stakeholders		regulatory uncertaint
7	Importance of collaboration with regulatory bodies		regulatory uncertaint
8	Importance of understanding both legal and market sentiment in innovation		regulatory uncertaint
9	Lack of intergovernmental standardisation, regulatory uncertainty		regulatory uncertaint
0	Lack of regulatory enforcement		regulatory uncertaint
1	Legal and competitive barriers to data sharing in supply chains		regulatory uncertaint
2	Legal and compliance challenges in data usage and permissions		regulatory uncertaint
3	Legal and regulatory challenges impact energy sector innovation		regulatory uncertaint
4	Low adoption rates due to lack of enforcement or penalties		regulatory uncertaint
5	Low fines allow companies to delay addressing sustainability issues		regulatory uncertaint
6	Market access requiring standardization		regulatory uncertaint
7	Market challenge: European response to tech monopolies and controlling data sharing		regulatory uncertaint
8	Market challenge: lack of coordination in innovation efforts		regulatory uncertaint
9	Misaligned assumptions on regulatory motivation		regulatory uncertaint
0	Multiple standards in sustainability as a challenge		regulatory uncertaint
1	Need for compliance and financial alignment for implementation		regulatory uncertaint
2	Regulation as market driver		regulatory uncertaint
3	Regulation-driven market demand		regulatory uncertaint
4	Regulation-driven motivation for adopting compliance solutions		regulatory uncertaint
5	Regulations are a driver in military, greenwashing enforcement	hackathon	regulatory uncertaint
6	Regulators should mandate but not develop standards themselves	hackathon	regulatory uncertaint
7	Regulatory changes make it harder to sell the product	hackathon	regulatory uncertaint
8	Regulatory compliance as a driver	hackathon	regulatory uncertaint
9	Regulatory enforcement in climate risk for financial sector	hackathon	regulatory uncertaint
0	Regulatory pressures in the EU	hackathon	regulatory uncertaint
1	Regulatory uncertainty as a barrier to innovation		regulatory uncertaint
2	Role of government enforcement in driving sustainable collaboration		regulatory uncertaint
3	Standardization as a critical enabler for digital solution adoption		regulatory uncertaint
4	Standardization as a primary issue in applying digital twins in the energy sector		regulatory uncertaint
5	Standardization critical to ensure market inclusion		regulatory uncertaint
6	Standardization needs to be enforced by regulators		regulatory uncertaint
7	Standardized measurements needed for benchmarking		regulatory uncertaint
8	The need to reduce regulatory burdens in supply chain management		regulatory uncertaint
9	The role of government legislation in driving energy efficiency		regulatory uncertaint
0	Time-consuming nature of aligning legal interpretations with operational realities		regulatory uncertaint
1	Uncertainty about future regulations		regulatory uncertaint

Stakeholder Misalignment

Key insights: Misalignment among stakeholders remains a major barrier to digital twin adoption. Poor communication, unclear accountability, and low digital literacy create gaps that slow decision-making and alignment. Technical jargon often alienates non-technical stakeholders, while mindset and cultural barriers hinder collaboration. Long engagement cycles with key decision-makers, particularly large organisations, amplify delays. Furthermore, conflicts over intellectual property and ownership models add complexity, making it difficult to establish clear roles and collaborative momentum.

1	Code		Thesis Category
784	Alignment of research and commercialisation varied between stakeholders		stakeholder misalignment
785	Because the experts do it in a certain way and can't even think of expressing, for them it's normal work. Getting that out of them and into a system, extremely difficult.		stakeholder misalignment
786	Building trust through transparancy in the resale market		stakeholder misalignment
787	Challenge: difficulty for outsiders to understand the specific needs and challenges of network operators		stakeholder misalignment
788	Challenge: misconception that there is a single digital twin for a physical reality		stakeholder misalignment
789	Challenges of working with remote famers and cooperatives		stakeholder misalignment
790	Communication challenges with programmers and policymakers		stakeholder misalignment
791	Complexity of cross-department integration within companies		stakeholder misalignment
792	Complexity of dealing with multiple stakeholders in urban digital twins		stakeholder misalignment
793	Compliance departments don't decide on buying new technologies, but they are a big stakeholder		stakeholder misalignment
794	Complications due to overlapping roles and responsibilities		stakeholder misalignment
795	Convincing CEOs is the primary obstacle		stakeholder misalignment
796	Coordination of multiple stakeholders with different goals		stakeholder misalignment
797	Cross-functional team requirements		stakeholder misalignment
798	Customer-related challenges in the energy transition		stakeholder misalignment
799	Dat wordt niet gezien door de netbeheerders als van belang		stakeholder misalignment
800	De bulk van de mensen die, moet je voorstellen, dat zijn programmeurs, of beleidsmensen. En bij beide klikt het niet.		stakeholder misalignment
801	de wetgever doet het precies andersom. Dus je ziet de wetgever veel meer ruimte geven voor gegevensdeling dan dat die netbeheerders ervaren dat ze hebben.		stakeholder misalignment
802	department-specific communication		stakeholder misalignment
803	Die elektrotechnici, die zijn echt dominant. En dat zijn vaak oude mannen. Ja, die zitten gewoon vast in hun manier van denken.		stakeholder misalignment
804	Different perspectives depending on role (e.g. operator vs. manufacturer)		stakeholder misalignment
805	Differentiation in understanding between tech vs. non-tech roles		stakeholder misalignment
806	Differing stakeholder opinions		stakeholder misalignment
807	Difficulty in accessing decision-makers within organisations		stakeholder misalignment
808	Difficulty in advocating for innovative solutions like digital twins		stakeholder misalignment
809	Difficulty in extracting implicit knowledge		stakeholder misalignment
810	Difficulty of convincing large companies with multiple layers of decision-makers		stakeholder misalignment
811	Difficulty of cross-functional teams		stakeholder misalignment
812	Disconnect between business process experts and tech developers		stakeholder misalignment
813	Diverse interests	hackathon	stakeholder misalignment
814	Diverse stakeholder needs and views on data management		stakeholder misalignment
815	Effective team dynamics		stakeholder misalignment
816	En beleidsmensen vinden het allemaal veel te gedetailleerd.	hackathon	stakeholder misalignment
817	External consultants brought in to facilitate the mindset shift	hackathon	stakeholder misalignment
818	Facilitating communication as a key role	hackathon	stakeholder misalignment
819	Het grootste obstakel is dat je met zoveel stakeholders rekening moet houden.		stakeholder misalignment
820	Het is geen Greenfield, het is altijd een transitievraagstuk. En dus, choose your battles wisely, sommige dingen zijn gewoon zoals ze zijn.		stakeholder misalignment
821	het is heel veel kletsen. Ik werk hier al negen maanden en je ziet de olietanken draaien.		stakeholder misalignment

822	I put up implicit knowledge. It's very difficult to get insights out of people if you want to design this digital twin.		stakeholder misalignment
823	Identifying mindset change as the biggest challenge		stakeholder misalignment
824	If you have the CEO on board and it's a lot easier than from the bottom up.		stakeholder misalignment
825	Importance of aligning customer and developer perspectives		stakeholder misalignment
826	Importance of collaboration between tech providers and supply chain experts		stakeholder misalignment
827	Importance of defining the solution with the industry		stakeholder misalignment
828	Importance of early customer conversations		stakeholder misalignment
829	Importance of early involvement to avoid process disruption		stakeholder misalignment
830	Importance of understanding and balancing customer needs		stakeholder misalignment
831	Involvement of multiple stakeholders, including residents and future occupants, in project planning		stakeholder misalignment
832	Iterative discussions for customer requirements	hackathon	stakeholder misalignment
833	Long feedback loops slowing down process		stakeholder misalignment
834	Long process to reach key decision makers		stakeholder misalignment
835	Manager roles have difficulty in understanding detailed technical discussions		stakeholder misalignment
836	Managing and aligning expectations between parties		stakeholder misalignment
837	Managing customer expectations		stakeholder misalignment
838	Managing customer expectations and versioning		stakeholder misalignment
839	Managing expectations and clarifying needs		stakeholder misalignment



840	Minset shift confirmed as the primary challenge in technology adoption		stakeholder misalignment
841	Misallocation of roles between Devops and DataOps teams		stakeholder misalignment
842	Multi-stakeholder problem with conflicting interests		stakeholder misalignment
843	Need for intermediaries to translate between tech and business		stakeholder misalignment
844	Need for shifts in design thinking and system development		stakeholder misalignment
845	Non-technical aspects of failures in the energy infrastructure		stakeholder misalignment
846	Not only use data to justify the efforts that we want to push forward.		stakeholder misalignment
847	On an organizational level there's quite a lot of people who don't want transparency. Because if you make something transparent you have to do something about it.		stakeholder misalignment
848	Practical challenge of changing mindsets to adopt new technology		stakeholder misalignment
849	Problem of conflicting interest in supply chain traceability projects		stakeholder misalignment
850	Reflection on dual-role challenges of manager also being the customer		stakeholder misalignment
851	Reliance on expert knowledge		stakeholder misalignment
852	Role of external consultants in translating business needs to tech solutions		stakeholder misalignment
853	Role of translator between customer and developer needs		stakeholder misalignment
854	Scale of DevOps and DataOps teams within energy sector organisations		stakeholder misalignment
855	So if you want to do a digital twin in a different domain, many people think, oh, that's the engineering stuff, the building stuff. Th		stakeholder misalignment
856	Stakeholder management complexity in supply chains		stakeholder misalignment
857	Stakeholder misalignment		stakeholder misalignment
858	Static mindset as a barrier to innovation		stakeholder misalignment
859	Third-party involvement often necessary for successful implementation		stakeholder misalignment
860	Top-down approach needed for effective change management		stakeholder misalignment
861	Trust as a central element in circularity and sustainability efforts		stakeholder misalignment
862	Trust as a key currency in supply chains and technology adoption		stakeholder misalignment
863	Typical development challenges in multi-stakeholder projects		stakeholder misalignment
864	Whole company cooperation		stakeholder misalignment
865	You also have the milestone tactics. That's top management geared. And then make sure that the top management kind of puts their neck at stake, so to speak.		stakeholder misalignment
866	You usually have different stakeholders at different levels and different interests. So that's why it's difficult to set a clear focus on what you want to achieve. Cannot make everyone happy.		stakeholder misalignment

Scalability Challenges

Key insights: Aligning digital twin technologies with specific industry needs while ensuring scalability is a persistent challenge. Companies struggle to customise solutions that integrate seamlessly with legacy systems and address sector-specific requirements. Efforts to differentiate from large tech providers by offering decentralised and specialised solutions are hindered by inconsistent market processes and limited data-sharing practices. Additionally, scalability issues arise when companies fail to anticipate broader applications beyond the initial pilot stages, limiting the potential impact of digital twin technologies.

1	Code		Thesis Category
729	Barrier: constant need for customization hinders innovation		scalability challenges
730	Competing with existing solutions (spreadsheets)		scalability challenges
731	Competitive landscape identified for dashboards		scalability challenges
732	Contractual agreements limiting flexibility in temperature management		scalability challenges
733	Er zijn zat mensen met goede ideeën. Er zijn ook zat mensen, vaak dezelfde, die ons het gefrustreerd worden van waarom komt mijn idee niet verder.		scalability challenges
734	Growth of competitor leading to multiple use cases		scalability challenges
735	If Shell's using it, BP doesn't wanna use it anymore.		scalability challenges
736	Incompatibility of systems between different industry players		scalability challenges
737	Je moet er gewoon vanuit gaan dat er een of andere motherfucker is die gewoon meer geld er aan wil verdienen. En dat moet je dus uitsluiten. En daar zit dus ook een waarde in wat zo'n digital twin kan brengen.		scalability challenges
738	Key players: big software and hardware providers dominate the market		scalability challenges
739	Maar de reden dat ik dat even niet doe is omdat als je niet op past, ben je gewoon een tech provider. Door al die andere tech providers		scalability challenges
740	Maar de wereld verandert nu heel snel en je ziet ook dat die processen niet meer kunnen bijhouden, de veranderingen kunnen bijhouden.		scalability challenges
741	Maersk's extensive in-house technology capabilities		scalability challenges
742	Maersk's external partnerships in digital twins for supply chain simulation		scalability challenges
743	Market competition: avoiding being just another tech provider		scalability challenges
744	Observation of diversity in tool development approaches		scalability challenges
745	Potential comparison with digital twins in other industries		scalability challenges
746	Resistance to competitor-used systems, competitive rivalry		scalability challenges
747	Scale challenge: managing many network operators across Europe		scalability challenges
748	Simple, flexible solutions (e.g. Power BI + python) for data integration		scalability challenges
749	Usability/Accessability concerns for wider organisation		scalability challenges
750	Use of in-house developed software for supply chain management		scalability challenges

C2. Organisational Barriers

Ambitions vs. Strategic Focus

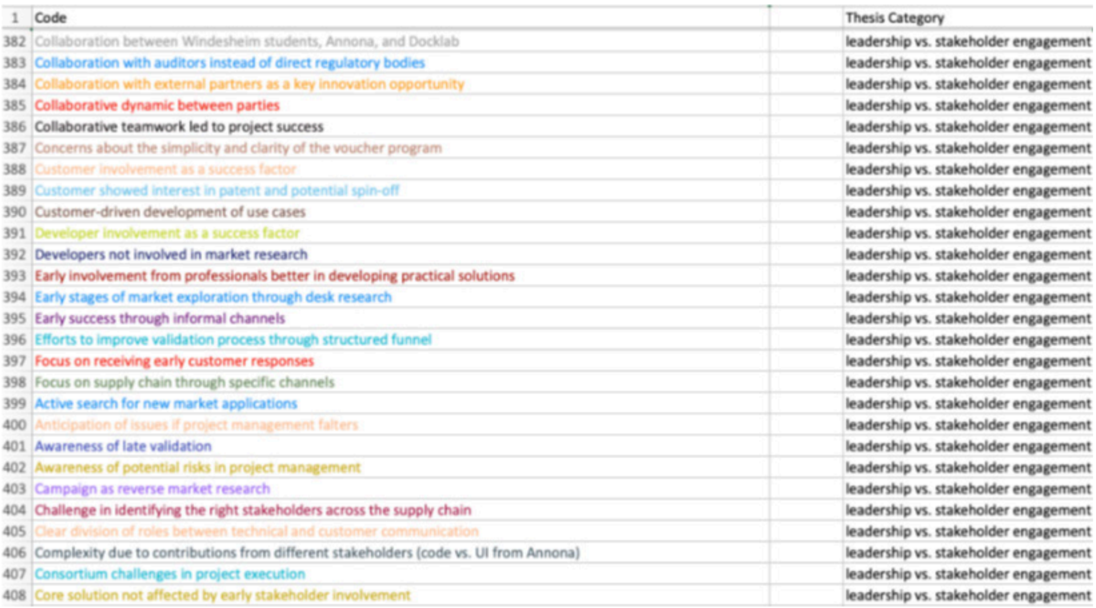
Key insights: Docklab has ambitions to scale and launch multiple projects per year. However, resource limitations and time management issues hinder progress. Leadership transitions and external factors disrupted project continuity early on. Additionally, Docklab's broad focus on multiple industries, rather than a specific market direction, has contributed to fragmentation. While the strategy shifted from research-driven to commercially driven after the consortium phase, the trial-and-error approach to market segments, evident in discarded explorations of coffee and construction, revealed the challenges of scaling without clear market prioritisation.

1	Code		Thesis Category
88	Ambition to launch 3 startups per year		ambitions vs. strategic focus
89	Availability of key resources (Vincent's expertise)		ambitions vs. strategic focus
90	Balancing innovation with ongoing operations		ambitions vs. strategic focus
91	Broad approach to market		ambitions vs. strategic focus
92	Campaign is broad and not yet focused on specific industries		ambitions vs. strategic focus
93	Challenges due to previous lack of resources or stakeholder alignment		ambitions vs. strategic focus
94	Collaboration challenges in pilot projects		ambitions vs. strategic focus
95	Continuation of development due to available resources (voucher)		Ambitions vs. strategic focus
96	Delay attributed to juggling multiple projects		ambitions vs. strategic focus
97	Downstream players as closer to end customers		ambitions vs. strategic focus
98	Downstream players' authority to influence upstream adoption		ambitions vs. strategic focus
99	Exploration of new market applications for the technology		ambitions vs. strategic focus
100	Exploring both broad and specific market research strategies to identify best results		ambitions vs. strategic focus
101	First three advice vouchers as milestones		ambitions vs. strategic focus
102	Flexibility in project size and additional investment		ambitions vs. strategic focus
103	Focus on SMEs in supply chain	hackathon	ambitions vs. strategic focus
104	Focus shifted to monetizing created solutions		ambitions vs. strategic focus
105	Fruitful first use case in a closed system		ambitions vs. strategic focus
106	Initial focus on hydrogen market		ambitions vs. strategic focus
107	Initial focus on multiple unique selling points		ambitions vs. strategic focus
108	Initial phase focused on research		ambitions vs. strategic focus
109	Lack of a dedicated market research team		ambitions vs. strategic focus
110	Lack of clear focus in market communication		ambitions vs. strategic focus
111	Lack of focus and time availability as barriers to progress		ambitions vs. strategic focus
112	Lack of focus and time constraints		ambitions vs. strategic focus
113	Lack of focus and time for business development		ambitions vs. strategic focus
114	Lack of initial problem validation		ambitions vs. strategic focus
115	Limited by resources and lack of dedicated sales team		ambitions vs. strategic focus
116	Limited direct customer involvement		ambitions vs. strategic focus
117	Limited resources affect ability to hire and focus		ambitions vs. strategic focus
118	Market research started only recently		ambitions vs. strategic focus
119	Market research started too late		ambitions vs. strategic focus
120	Milestones for campaign (launch and company submissions)		ambitions vs. strategic focus
121	Mismatch between resources and number of projects		ambitions vs. strategic focus
122	Multiple priority projects and limited budgets		ambitions vs. strategic focus
123	Next phase of project development with additional funding		ambitions vs. strategic focus
124	Optimism about solution once challenges are addressed		ambitions vs. strategic focus
125	ownership and budget failures in past projects		ambitions vs. strategic focus
126	Patent discussions alongside ownership conversations		ambitions vs. strategic focus
127	Positive reception by Annona		ambitions vs. strategic focus
128	Potential for broader applications beyond deep tier financing		ambitions vs. strategic focus
129	Potential for future development despite unresolved ownership		ambitions vs. strategic focus
130	Potential for multiple applications or use cases		ambitions vs. strategic focus
131	Potential resolution of time issues through additional resources		ambitions vs. strategic focus
132	Prioritization issues affecting progress		ambitions vs. strategic focus
133	Problem-solving through blockchain technology		ambitions vs. strategic focus
134	Project built without early feedback but continued with voucher funding		ambitions vs. strategic focus
135	Project did not progress far enough to address key questions		ambitions vs. strategic focus
136	Project initiation upon successful voucher acquisition		ambitions vs. strategic focus
137	Proof of concept developed by Docklab and Windesheim students		ambitions vs. strategic focus
138	Proof of concept successfully demonstrated but not tested		ambitions vs. strategic focus
139	Recognition of customer ambition and long-term ideas		ambitions vs. strategic focus
140	Reuse of Docklab's existing technologies (QuayConnect)		ambitions vs. strategic focus
141	Searching for applications		ambitions vs. strategic focus
142	Strategic focus on finding an industry		ambitions vs. strategic focus
143	Strategy for general campaign publication		ambitions vs. strategic focus
144	Strategy to track competitor's progress via archived websites		ambitions vs. strategic focus
145	Success with biofuels market entry		ambitions vs. strategic focus
146	Suggestion for targeted marketing campaign		ambitions vs. strategic focus
147	Tailoring NexTwin per business case		ambitions vs. strategic focus
148	Time constraints as a challenge		ambitions vs. strategic focus
149	Two-way strategy: vouchers program and specific market exploration		ambitions vs. strategic focus
150	Uncertainty about outcomes with previous research projects if the voucher program was already there		ambitions vs. strategic focus
151	Uncertainty about what blocked previous projects		ambitions vs. strategic focus
152	unclear project needs		ambitions vs. strategic focus

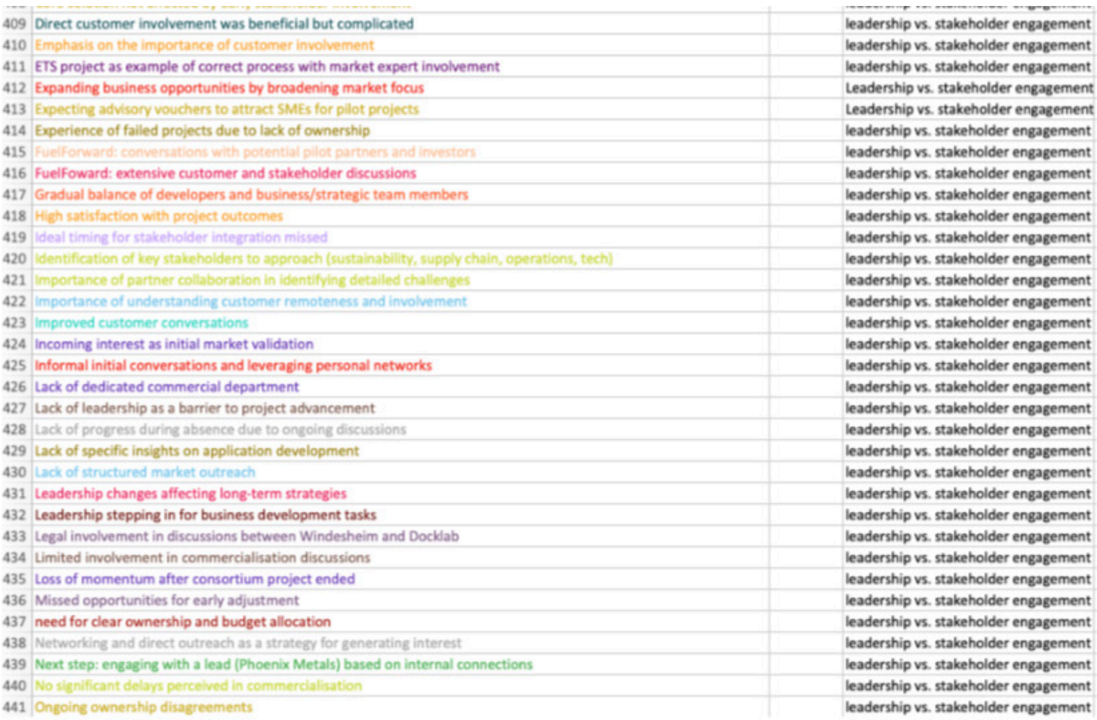
Scaling technology vs. Integration challenges
Key insights: NexTwin was designed to be scalable and modular, offering flexibility across industries. However, integration challenges arise due to the reliance on legacy systems and the customisation required in sectors with strict operational frameworks, such as energy. The stalled construction initiative with VDR highlights the impact of high pilot costs on integration feasibility, underscoring how cost sensitivity limits the broader application of the technology. Ownership and standardisation issues also remain unresolved, further complicating scalability.

1	Code	Thesis Category
751	Collaborative ownership model discussed for future applications	scaling technology vs. integration challenges
752	Attempts to implement solutions with another customer	scaling technology vs. integration challenges
753	Building specific modules on top of the core digital twin solution	scaling technology vs. integration challenges
754	Competitor seen as a generalist instead of a specialist	scaling technology vs. integration challenges
755	Competitor/Partnership: collaborating with companies specializing in digital twins	scaling technology vs. integration challenges
756	Competitors expanding into other use cases	scaling technology vs. integration challenges
757	Concerns about scalability of digital product passports across industries	scaling technology vs. integration challenges
758	Confidence in NexTwin's ability to solve high-level transparency issues	scaling technology vs. integration challenges
759	Confirmation that project faced challenges due to identified risks	scaling technology vs. integration challenges
760	Consortium's end triggered focus on financial incentive	scaling technology vs. integration challenges
761	Continuous feedback loops and iterative development in ETS project	scaling technology vs. integration challenges
762	Customization depends on client type and problem complexity	scaling technology vs. integration challenges
763	Customization for each business case or niche application	scaling technology vs. integration challenges
764	Customizing tech solutions to specific assets as a roadblock	scaling technology vs. integration challenges
765	Flexibility in applying NexTwin to different use cases based on client needs	Scaling technology vs. integration challenges
766	Flexibility in blockchain for data security	scaling technology vs. integration challenges
767	Flexibility of components developed during the project	scaling technology vs. integration challenges
768	High-level work preventing significant challenges from arising	scaling technology vs. integration challenges
769	Importance of phased development and validation	scaling technology vs. integration challenges
770	Issue: customization makes it difficult to standardize and scale products	scaling technology vs. integration challenges
771	Lack of experience with physical technology at Docklab	scaling technology vs. integration challenges
772	Lack of further implementation as a reason for fewer obstacles	scaling technology vs. integration challenges
773	Lack of real-world testing with actual data	scaling technology vs. integration challenges
774	Legal advice sought for patenting solutions	scaling technology vs. integration challenges
775	Limited blockchain use cases, suitable for product passports	scaling technology vs. integration challenges
776	Opportunity to re-evaluate competitor	scaling technology vs. integration challenges
777	Pilots conducted but failed to sell the service	scaling technology vs. integration challenges
778	Pilots projects seen as useful, but shelved due to investment hesitancy	scaling technology vs. integration challenges
779	Potential for more extensibility in technology	scaling technology vs. integration challenges
780	Potential scalability of developed material passport	scaling technology vs. integration challenges
781	Scalability of NexTwin based on its modular design	scaling technology vs. integration challenges
782	Success in creating scalable components	scaling technology vs. integration challenges
783	Tech companies' reluctance to restructure products for specific needs	scaling technology vs. integration challenges

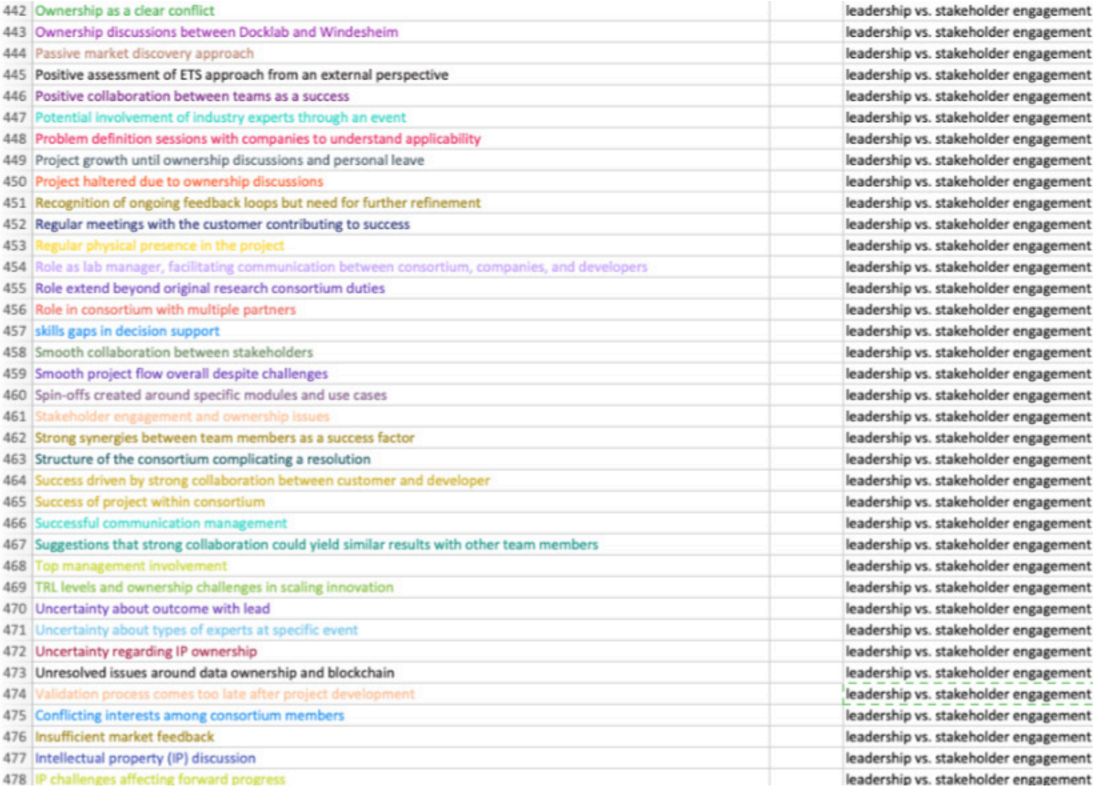
Leadership vs. Stakeholder engagement
Key insights: Docklab's reliance on reactive strategies, such as voucher programs to gauge industry interest, reflects gaps in proactive commercial leadership. This lack of a unified strategic focus has hindered customer engagement and delayed progress, as seen in ownership disagreements during the consortium. NexTwin's development further highlights these challenges, with insufficient structured stakeholder involvement after the proof-of-concept phase leading to missed opportunities for aligning its features and value proposition with market needs. In contrast, the consistent customer involvement in Annona's early success underscores the importance of proactive leadership and early stakeholder engagement in driving market validation and commercial success.



1	Code	Thesis Category
382	Collaboration between Windesheim students, Annona, and Docklab	leadership vs. stakeholder engagement
383	Collaboration with auditors instead of direct regulatory bodies	leadership vs. stakeholder engagement
384	Collaboration with external partners as a key innovation opportunity	leadership vs. stakeholder engagement
385	Collaborative dynamic between parties	leadership vs. stakeholder engagement
386	Collaborative teamwork led to project success	leadership vs. stakeholder engagement
387	Concerns about the simplicity and clarity of the voucher program	leadership vs. stakeholder engagement
388	Customer involvement as a success factor	leadership vs. stakeholder engagement
389	Customer showed interest in patent and potential spin-off	leadership vs. stakeholder engagement
390	Customer-driven development of use cases	leadership vs. stakeholder engagement
391	Developer involvement as a success factor	leadership vs. stakeholder engagement
392	Developers not involved in market research	leadership vs. stakeholder engagement
393	Early involvement from professionals better in developing practical solutions	leadership vs. stakeholder engagement
394	Early stages of market exploration through desk research	leadership vs. stakeholder engagement
395	Early success through informal channels	leadership vs. stakeholder engagement
396	Efforts to improve validation process through structured funnel	leadership vs. stakeholder engagement
397	Focus on receiving early customer responses	leadership vs. stakeholder engagement
398	Focus on supply chain through specific channels	leadership vs. stakeholder engagement
399	Active search for new market applications	leadership vs. stakeholder engagement
400	Anticipation of issues if project management falters	leadership vs. stakeholder engagement
401	Awareness of late validation	leadership vs. stakeholder engagement
402	Awareness of potential risks in project management	leadership vs. stakeholder engagement
403	Campaign as reverse market research	leadership vs. stakeholder engagement
404	Challenge in identifying the right stakeholders across the supply chain	leadership vs. stakeholder engagement
405	Clear division of roles between technical and customer communication	leadership vs. stakeholder engagement
406	Complexity due to contributions from different stakeholders (code vs. UI from Annona)	leadership vs. stakeholder engagement
407	Consortium challenges in project execution	leadership vs. stakeholder engagement
408	Core solution not affected by early stakeholder involvement	leadership vs. stakeholder engagement



409	Direct customer involvement was beneficial but complicated		leadership vs. stakeholder engagement
410	Emphasis on the importance of customer involvement		leadership vs. stakeholder engagement
411	ETS project as example of correct process with market expert involvement		leadership vs. stakeholder engagement
412	Expanding business opportunities by broadening market focus		Leadership vs. stakeholder engagement
413	Expecting advisory vouchers to attract SMEs for pilot projects		Leadership vs. stakeholder engagement
414	Experience of failed projects due to lack of ownership		leadership vs. stakeholder engagement
415	FuelForward: conversations with potential pilot partners and investors		leadership vs. stakeholder engagement
416	FuelFoward: extensive customer and stakeholder discussions		leadership vs. stakeholder engagement
417	Gradual balance of developers and business/strategic team members		leadership vs. stakeholder engagement
418	High satisfaction with project outcomes		leadership vs. stakeholder engagement
419	Ideal timing for stakeholder integration missed		leadership vs. stakeholder engagement
420	Identification of key stakeholders to approach (sustainability, supply chain, operations, tech)		leadership vs. stakeholder engagement
421	Importance of partner collaboration in identifying detailed challenges		leadership vs. stakeholder engagement
422	Importance of understanding customer remoteness and involvement		leadership vs. stakeholder engagement
423	Improved customer conversations		leadership vs. stakeholder engagement
424	Incoming interest as initial market validation		leadership vs. stakeholder engagement
425	Informal initial conversations and leveraging personal networks		leadership vs. stakeholder engagement
426	Lack of dedicated commercial department		leadership vs. stakeholder engagement
427	Lack of leadership as a barrier to project advancement		leadership vs. stakeholder engagement
428	Lack of progress during absence due to ongoing discussions		leadership vs. stakeholder engagement
429	Lack of specific insights on application development		leadership vs. stakeholder engagement
430	Lack of structured market outreach		leadership vs. stakeholder engagement
431	Leadership changes affecting long-term strategies		leadership vs. stakeholder engagement
432	Leadership stepping in for business development tasks		leadership vs. stakeholder engagement
433	Legal involvement in discussions between Windesheim and Docklab		leadership vs. stakeholder engagement
434	Limited involvement in commercialisation discussions		leadership vs. stakeholder engagement
435	Loss of momentum after consortium project ended		leadership vs. stakeholder engagement
436	Missed opportunities for early adjustment		leadership vs. stakeholder engagement
437	need for clear ownership and budget allocation		leadership vs. stakeholder engagement
438	Networking and direct outreach as a strategy for generating interest		leadership vs. stakeholder engagement
439	Next step: engaging with a lead (Phoenix Metals) based on internal connections		leadership vs. stakeholder engagement
440	No significant delays perceived in commercialisation		leadership vs. stakeholder engagement
441	Ongoing ownership disagreements		leadership vs. stakeholder engagement



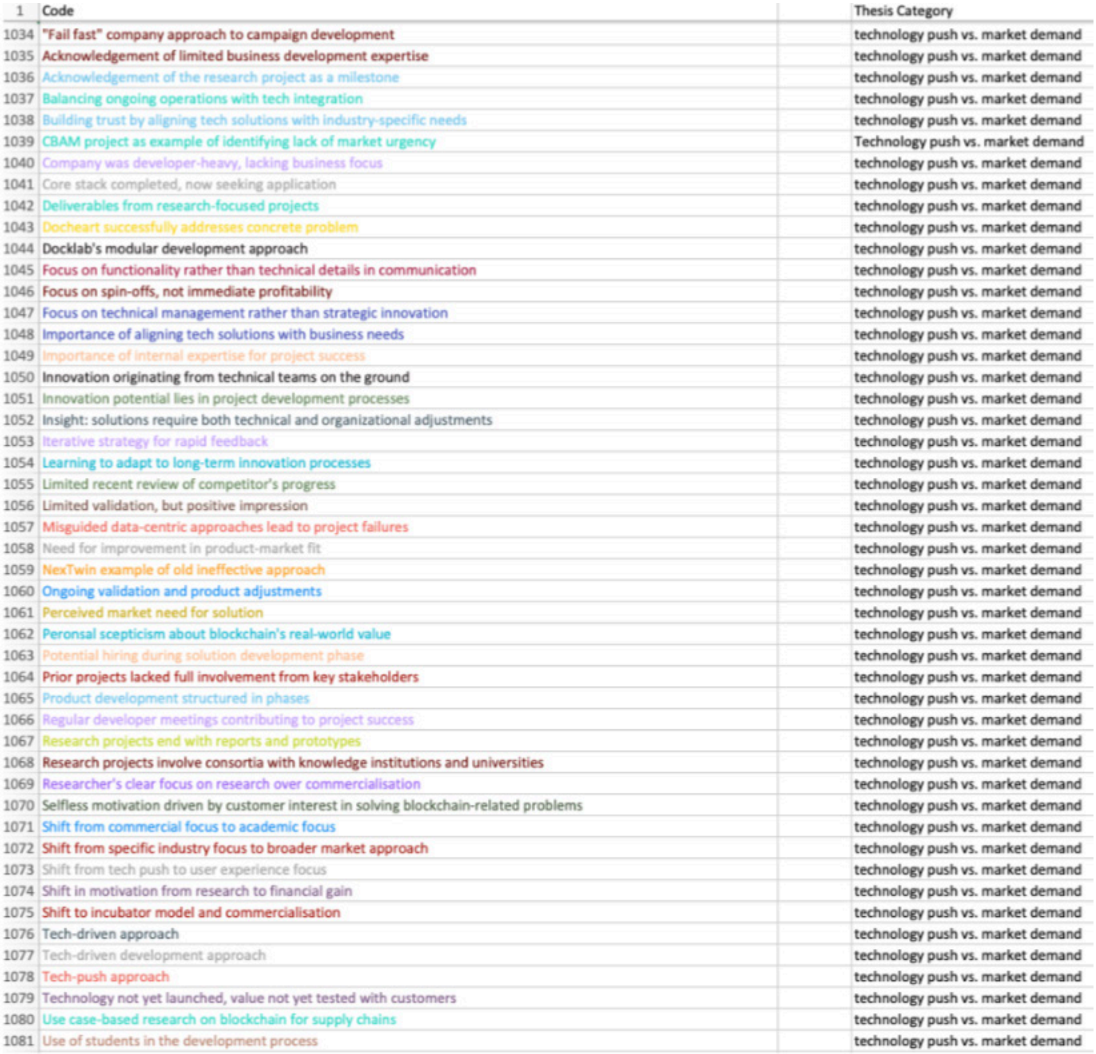
442	Ownership as a clear conflict		leadership vs. stakeholder engagement
443	Ownership discussions between Docklab and Windesheim		leadership vs. stakeholder engagement
444	Passive market discovery approach		leadership vs. stakeholder engagement
445	Positive assessment of ETS approach from an external perspective		leadership vs. stakeholder engagement
446	Positive collaboration between teams as a success		leadership vs. stakeholder engagement
447	Potential involvement of industry experts through an event		leadership vs. stakeholder engagement
448	Problem definition sessions with companies to understand applicability		leadership vs. stakeholder engagement
449	Project growth until ownership discussions and personal leave		leadership vs. stakeholder engagement
450	Project haltered due to ownership discussions		leadership vs. stakeholder engagement
451	Recognition of ongoing feedback loops but need for further refinement		leadership vs. stakeholder engagement
452	Regular meetings with the customer contributing to success		leadership vs. stakeholder engagement
453	Regular physical presence in the project		leadership vs. stakeholder engagement
454	Role as lab manager, facilitating communication between consortium, companies, and developers		leadership vs. stakeholder engagement
455	Role extend beyond original research consortium duties		leadership vs. stakeholder engagement
456	Role in consortium with multiple partners		leadership vs. stakeholder engagement
457	skills gaps in decision support		leadership vs. stakeholder engagement
458	Smooth collaboration between stakeholders		leadership vs. stakeholder engagement
459	Smooth project flow overall despite challenges		leadership vs. stakeholder engagement
460	Spin-offs created around specific modules and use cases		leadership vs. stakeholder engagement
461	Stakeholder engagement and ownership issues		leadership vs. stakeholder engagement
462	Strong synergies between team members as a success factor		leadership vs. stakeholder engagement
463	Structure of the consortium complicating a resolution		leadership vs. stakeholder engagement
464	Success driven by strong collaboration between customer and developer		leadership vs. stakeholder engagement
465	Success of project within consortium		leadership vs. stakeholder engagement
466	Successful communication management		leadership vs. stakeholder engagement
467	Suggestions that strong collaboration could yield similar results with other team members		leadership vs. stakeholder engagement
468	Top management involvement		leadership vs. stakeholder engagement
469	TRL levels and ownership challenges in scaling innovation		leadership vs. stakeholder engagement
470	Uncertainty about outcome with lead		leadership vs. stakeholder engagement
471	Uncertainty about types of experts at specific event		leadership vs. stakeholder engagement
472	Uncertainty regarding IP ownership		leadership vs. stakeholder engagement
473	Unresolved issues around data ownership and blockchain		leadership vs. stakeholder engagement
474	Validation process comes too late after project development		leadership vs. stakeholder engagement
475	Conflicting interests among consortium members		leadership vs. stakeholder engagement
476	Insufficient market feedback		leadership vs. stakeholder engagement
477	Intellectual property (IP) discussion		leadership vs. stakeholder engagement
478	IP challenges affecting forward progress		leadership vs. stakeholder engagement

Market alignment vs. Value proposition clarity

Key insights: Docklab’s iterative development process offers flexibility but slows commercialisation due to limited early stakeholder engagement, restricting validation and feedback opportunities. This misalignment has hindered NexTwin’s ability to adapt to market-specific needs, emphasising the importance of balancing iterative development with a stronger market focus. Additionally, NexTwin’s market appeal is weakened by an unclear and unfocused value proposition. While the proof of concept demonstrated potential, the lack of real-world data to substantiate return on investment (ROI) and a sharp differentiation from competing solutions, such as product passports and standard digital twins, reduces its impact. Addressing these gaps with a clear emphasis on actionable insights and commercial incentives is critical to strengthening

1	Code		Thesis Category
479	Failed market attemps (coffee and construction)		market alignment vs. value proposition clarity
480	Lack of focus in communicating NexTwin's value proposition		market alignment vs. value proposition clarity
481	Listing potential use cases to explain NexTwin's versatility		market alignment vs. value proposition clarity
482	Mismatch in market readiness, pilot in biofuels as reponse		market alignment vs. value proposition clarity
483	Modularity of core solution to fit specific use cases		market alignment vs. value proposition clarity
484	Multiple options available without a singular focus		market alignment vs. value proposition clarity
485	Need for relatable examples in communication		market alignment vs. value proposition clarity
486	NexTwin as a core solution, requires additional functionality for full supply chain integration		market alignment vs. value proposition clarity
487	NexTwin as a general and adaptable product		market alignment vs. value proposition clarity
488	NexTwin as a general solution applicable to various contexts		market alignment vs. value proposition clarity
489	NexTwin as tech stack, not a standalone company		market alignment vs. value proposition clarity
490	NexTwin can be implemented as a stand-along or integrated with larger systems		market alignment vs. value proposition clarity
491	NexTwin's ability to address transparency and information sharing in supply chains		market alignment vs. value proposition clarity
492	NexTwin's role in creating tailored solutions with a focus on transparency		market alignment vs. value proposition clarity
493	Opportunity: creating a value proposition that simplifies integration for customers		market alignment vs. value proposition clarity
494	Process of evaluating and engaging companies for vouchers		market alignment vs. value proposition clarity
495	Product solves a specific business problem, easy to sell without complex integration		market alignment vs. value proposition clarity
496	Annona was the client and Docklab was the tech provider		market alignment vs. value proposition clarity
497	Blockchain as a tool, not the end goal		market alignment vs. value proposition clarity
498	Broad range of potential market applications considered		market alignment vs. value proposition clarity
499	Broad scope of campaign to gather various use cases		market alignment vs. value proposition clarity
500	Challenge of capturing expert knowledge		market alignment vs. value proposition clarity
501	Collaborative problem-solving with clients		market alignment vs. value proposition clarity
502	Collaborative proposal creation and independent assessment process		market alignment vs. value proposition clarity
503	Communicating that profitability is not dependent on full supply chain participation		market alignment vs. value proposition clarity
504	Complexity and intimidation of digital twin and blockchain concepts for non-tech stakeholders		market alignment vs. value proposition clarity
505	Complexity of explaining interconnected offerings (vouchers, Docklab, NexTwin)		market alignment vs. value proposition clarity
506	Concern about communication and technical jargon being a barrier for non-tech stakeholders		market alignment vs. value proposition clarity
507	Concern about overuse or misapplication of the term 'digital twin'		market alignment vs. value proposition clarity
508	Confusion within organisations about the role of digital twin technology		market alignment vs. value proposition clarity
509	Core solution seen as abstract and foundational		market alignment vs. value proposition clarity
510	Difficulty in setting clear objectives		market alignment vs. value proposition clarity
511	Digital product passports as core strength		market alignment vs. value proposition clarity
512	Doubt about traditional industries grasping the technology	hackathon	market alignment vs. value proposition clarity
513	Early validation from industry event	hackathon	market alignment vs. value proposition clarity
514	Emphasis on regulatory expertise in project success	hackathon	market alignment vs. value proposition clarity
515	Explaining use cases through relatable examples helps in communication	hackathon	Market alignment vs. value proposition clarity
516	Exploration of blockchain technologies for supply chains as initial research goal	hackathon	market alignment vs. value proposition clarity
517	Fuel Forward searching for first customers, raised significant funding for hydrogen, but for a non-existing market	hackathon	market alignment vs. value proposition clarity
518	FuelForward: shifted focus to add value even if used by one entity	hackathon	market alignment vs. value proposition clarity
519	General solution adapted for multiple use cases	hackathon	market alignment vs. value proposition clarity
520	Goal of campaign to identify business cases		market alignment vs. value proposition clarity
521	High-level phases remain consistent, with details changing per industry		market alignment vs. value proposition clarity
522	High-level solution focs of NexTwin		market alignment vs. value proposition clarity
523	Importance of explaining outcomes rather than technical processes		market alignment vs. value proposition clarity
524	Individual focus on EV batteries		market alignment vs. value proposition clarity
525	Personal doubt about campaign design		market alignment vs. value proposition clarity
526	Potential gap in conveying the value and applicability of NexTwin		market alignment vs. value proposition clarity
527	Questioning whether to mention blockchain in explanations		market alignment vs. value proposition clarity
528	Realization of non-viable market segment (registration)		market alignment vs. value proposition clarity
529	Simpler product and solution as a strength		market alignment vs. value proposition clarity
530	Strategy to engage downstream players in the supply chain		market alignment vs. value proposition clarity
531	Suggestion to focus on one achievable market first, gradual expansion after		market alignment vs. value proposition clarity
532	Suggestions for researching project failures and successes in supply chain traceability		market alignment vs. value proposition clarity
533	Tailoring communication and solutions to different audiences		market alignment vs. value proposition clarity
534	Tailoring tech pitches to specific industries for better adoption		market alignment vs. value proposition clarity
535	Uncertainty about customer understanding of Docklab and its offerings		market alignment vs. value proposition clarity
536	Uncertainty about future customer understanding		market alignment vs. value proposition clarity
537	Uncertainty about how diverse industries will perceive the product		market alignment vs. value proposition clarity
538	Unsure about implementation in different industries		market alignment vs. value proposition clarity

Technology push vs. Market demand
Key insights: NexTwin's development was largely driven by a technology-push approach, focusing on innovation without consistently considering market demands. This approach, evident in failed applications to coffee and construction markets, delayed progress toward achieving a product-market fit. For example, blockchain integration, while initially promising, revealed the difficulties of balancing technical capabilities with practical applications. These experiences underscore the need to combine technological innovation with tangible market validation to achieve sustainable commercial success.

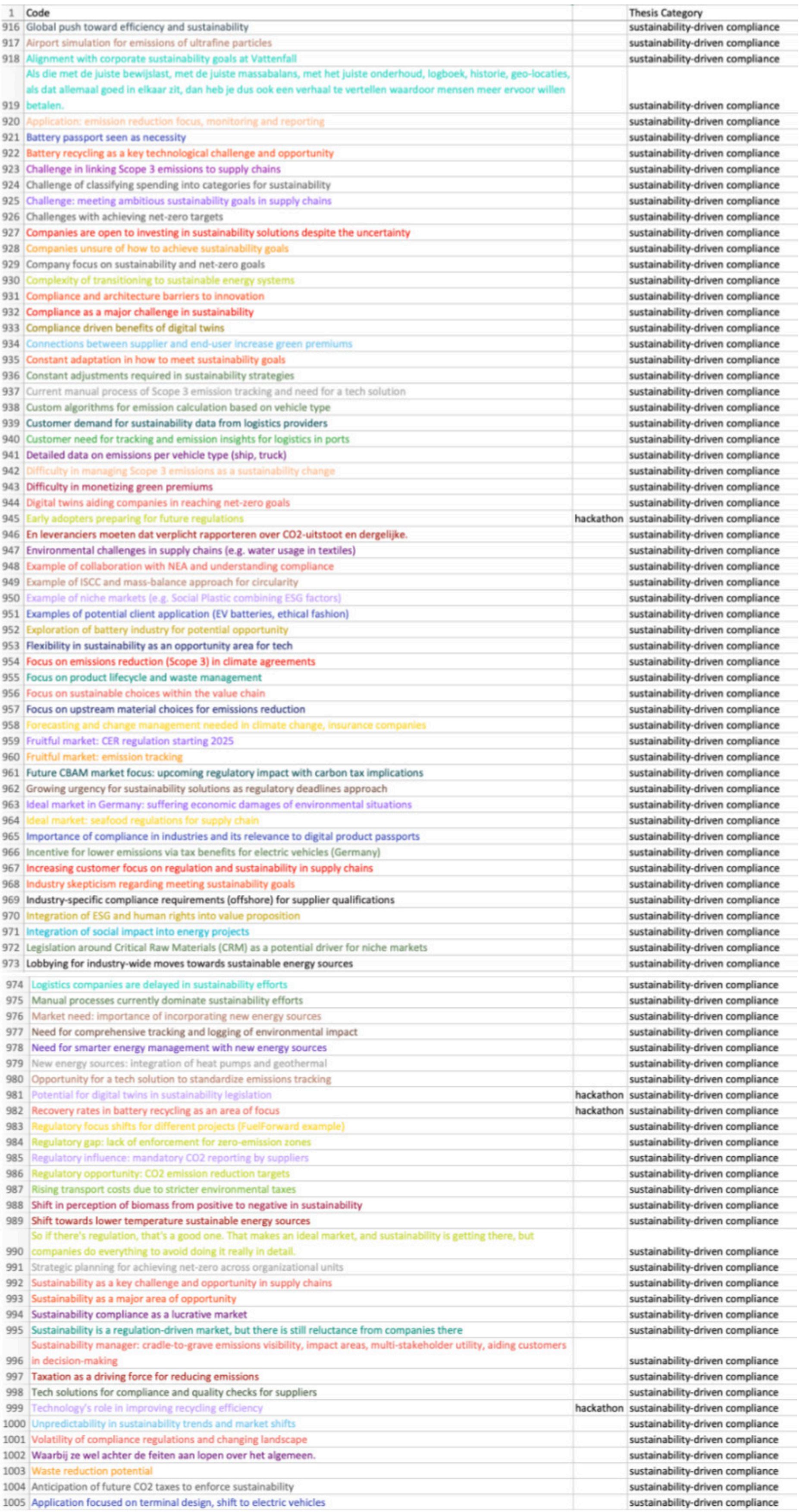


1	Code	Thesis Category
1034	"Fail fast" company approach to campaign development	technology push vs. market demand
1035	Acknowledgement of limited business development expertise	technology push vs. market demand
1036	Acknowledgement of the research project as a milestone	technology push vs. market demand
1037	Balancing ongoing operations with tech integration	technology push vs. market demand
1038	Building trust by aligning tech solutions with industry-specific needs	technology push vs. market demand
1039	CBAM project as example of identifying lack of market urgency	Technology push vs. market demand
1040	Company was developer-heavy, lacking business focus	technology push vs. market demand
1041	Core stack completed, now seeking application	technology push vs. market demand
1042	Deliverables from research-focused projects	technology push vs. market demand
1043	Docheart successfully addresses concrete problem	technology push vs. market demand
1044	Docklab's modular development approach	technology push vs. market demand
1045	Focus on functionality rather than technical details in communication	technology push vs. market demand
1046	Focus on spin-offs, not immediate profitability	technology push vs. market demand
1047	Focus on technical management rather than strategic innovation	technology push vs. market demand
1048	Importance of aligning tech solutions with business needs	technology push vs. market demand
1049	Importance of internal expertise for project success	technology push vs. market demand
1050	Innovation originating from technical teams on the ground	technology push vs. market demand
1051	Innovation potential lies in project development processes	technology push vs. market demand
1052	Insight: solutions require both technical and organizational adjustments	technology push vs. market demand
1053	Iterative strategy for rapid feedback	technology push vs. market demand
1054	Learning to adapt to long-term innovation processes	technology push vs. market demand
1055	Limited recent review of competitor's progress	technology push vs. market demand
1056	Limited validation, but positive impression	technology push vs. market demand
1057	Misguided data-centric approaches lead to project failures	technology push vs. market demand
1058	Need for improvement in product-market fit	technology push vs. market demand
1059	NexTwin example of old ineffective approach	technology push vs. market demand
1060	Ongoing validation and product adjustments	technology push vs. market demand
1061	Perceived market need for solution	technology push vs. market demand
1062	Peronsal scepticism about blockchain's real-world value	technology push vs. market demand
1063	Potential hiring during solution development phase	technology push vs. market demand
1064	Prior projects lacked full involvement from key stakeholders	technology push vs. market demand
1065	Product development structured in phases	technology push vs. market demand
1066	Regular developer meetings contributing to project success	technology push vs. market demand
1067	Research projects end with reports and prototypes	technology push vs. market demand
1068	Research projects involve consortia with knowledge institutions and universities	technology push vs. market demand
1069	Researcher's clear focus on research over commercialisation	technology push vs. market demand
1070	Selfless motivation driven by customer interest in solving blockchain-related problems	technology push vs. market demand
1071	Shift from commercial focus to academic focus	technology push vs. market demand
1072	Shift from specific industry focus to broader market approach	technology push vs. market demand
1073	Shift from tech push to user experience focus	technology push vs. market demand
1074	Shift in motivation from research to financial gain	technology push vs. market demand
1075	Shift to incubator model and commercialisation	technology push vs. market demand
1076	Tech-driven approach	technology push vs. market demand
1077	Tech-driven development approach	technology push vs. market demand
1078	Tech-push approach	technology push vs. market demand
1079	Technology not yet launched, value not yet tested with customers	technology push vs. market demand
1080	Use case-based research on blockchain for supply chains	technology push vs. market demand
1081	Use of students in the development process	technology push vs. market demand

C3. Industry Dynamics

Sustainability-driven compliance

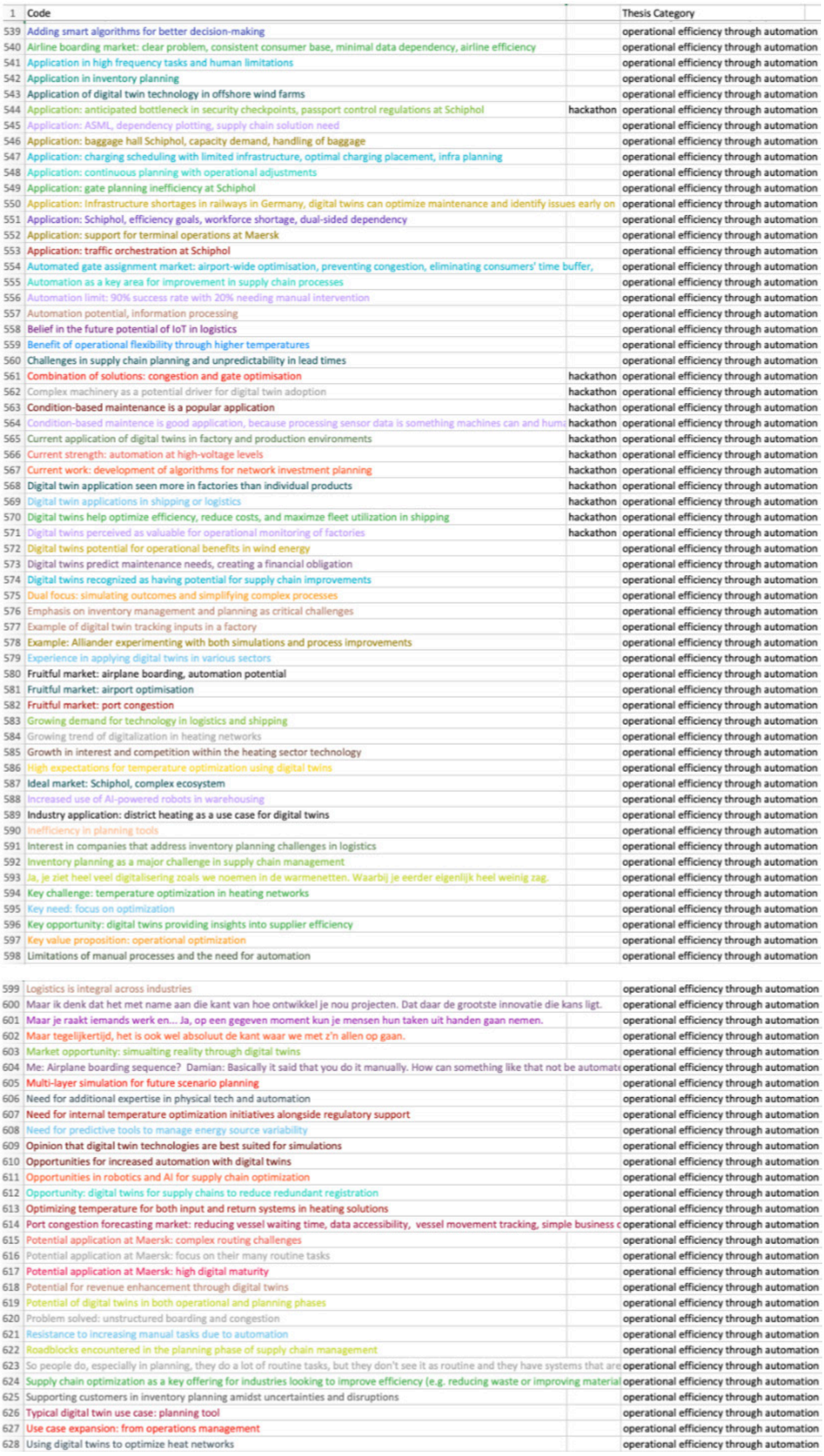
Key insights: Sustainability and regulatory compliance have become central to the adoption of new technologies, especially in sectors like energy and supply chain management. Companies are increasingly leveraging digital tools such as digital twins and blockchain to enhance transparency, monitor emissions (e.g. Scope 3), and manage compliance with evolving regulations. These technologies enable businesses to meet sustainability targets, track their progress toward net-zero goals, and audit operations efficiently. Additionally, businesses are navigating a fine balance between meeting customer-driven sustainability preferences and reacting to compliance mandates, which are often regulatory in nature.



1	Code		Thesis Category
916	Global push toward efficiency and sustainability		sustainability-driven compliance
917	Airport simulation for emissions of ultrafine particles		sustainability-driven compliance
918	Alignment with corporate sustainability goals at Vattenfall		sustainability-driven compliance
919	Als die met de juiste bewijslast, met de juiste massabalans, met het juiste onderhoud, logboek, historie, geo-locaties, als dat allemaal goed in elkaar zit, dan heb je dus ook een verhaal te vertellen waardoor mensen meer ervoor willen betalen.		sustainability-driven compliance
920	Application: emission reduction focus, monitoring and reporting		sustainability-driven compliance
921	Battery passport seen as necessity		sustainability-driven compliance
922	Battery recycling as a key technological challenge and opportunity		sustainability-driven compliance
923	Challenge in linking Scope 3 emissions to supply chains		sustainability-driven compliance
924	Challenge of classifying spending into categories for sustainability		sustainability-driven compliance
925	Challenge: meeting ambitious sustainability goals in supply chains		sustainability-driven compliance
926	Challenges with achieving net-zero targets		sustainability-driven compliance
927	Companies are open to investing in sustainability solutions despite the uncertainty		sustainability-driven compliance
928	Companies unsure of how to achieve sustainability goals		sustainability-driven compliance
929	Company focus on sustainability and net-zero goals		sustainability-driven compliance
930	Complexity of transitioning to sustainable energy systems		sustainability-driven compliance
931	Compliance and architecture barriers to innovation		sustainability-driven compliance
932	Compliance as a major challenge in sustainability		sustainability-driven compliance
933	Compliance driven benefits of digital twins		sustainability-driven compliance
934	Connections between supplier and end-user increase green premiums		sustainability-driven compliance
935	Constant adaptation in how to meet sustainability goals		sustainability-driven compliance
936	Constant adjustments required in sustainability strategies		sustainability-driven compliance
937	Current manual process of Scope 3 emission tracking and need for a tech solution		sustainability-driven compliance
938	Custom algorithms for emission calculation based on vehicle type		sustainability-driven compliance
939	Customer demand for sustainability data from logistics providers		sustainability-driven compliance
940	Customer need for tracking and emission insights for logistics in ports		sustainability-driven compliance
941	Detailed data on emissions per vehicle type (ship, truck)		sustainability-driven compliance
942	Difficulty in managing Scope 3 emissions as a sustainability change		sustainability-driven compliance
943	Difficulty in monetizing green premiums		sustainability-driven compliance
944	Digital twins aiding companies in reaching net-zero goals		sustainability-driven compliance
945	Early adopters preparing for future regulations	hackathon	sustainability-driven compliance
946	En leveranciers moeten dat verplicht rapporteren over CO2-uitstoot en dergelijke.		sustainability-driven compliance
947	Environmental challenges in supply chains (e.g. water usage in textiles)		sustainability-driven compliance
948	Example of collaboration with NEA and understanding compliance		sustainability-driven compliance
949	Example of ISCC and mass-balance approach for circularity		sustainability-driven compliance
950	Example of niche markets (e.g. Social Plastic combining ESG factors)		sustainability-driven compliance
951	Examples of potential client application (EV batteries, ethical fashion)		sustainability-driven compliance
952	Exploration of battery industry for potential opportunity		sustainability-driven compliance
953	Flexibility in sustainability as an opportunity area for tech		sustainability-driven compliance
954	Focus on emissions reduction (Scope 3) in climate agreements		sustainability-driven compliance
955	Focus on product lifecycle and waste management		sustainability-driven compliance
956	Focus on sustainable choices within the value chain		sustainability-driven compliance
957	Focus on upstream material choices for emissions reduction		sustainability-driven compliance
958	Forecasting and change management needed in climate change, insurance companies		sustainability-driven compliance
959	Fruitful market: CER regulation starting 2025		sustainability-driven compliance
960	Fruitful market: emission tracking		sustainability-driven compliance
961	Future CBAM market focus: upcoming regulatory impact with carbon tax implications		sustainability-driven compliance
962	Growing urgency for sustainability solutions as regulatory deadlines approach		sustainability-driven compliance
963	Ideal market in Germany: suffering economic damages of environmental situations		sustainability-driven compliance
964	Ideal market: seafood regulations for supply chain		sustainability-driven compliance
965	Importance of compliance in industries and its relevance to digital product passports		sustainability-driven compliance
966	Incentive for lower emissions via tax benefits for electric vehicles (Germany)		sustainability-driven compliance
967	Increasing customer focus on regulation and sustainability in supply chains		sustainability-driven compliance
968	Industry skepticism regarding meeting sustainability goals		sustainability-driven compliance
969	Industry-specific compliance requirements (offshore) for supplier qualifications		sustainability-driven compliance
970	Integration of ESG and human rights into value proposition		sustainability-driven compliance
971	Integration of social impact into energy projects		sustainability-driven compliance
972	Legislation around Critical Raw Materials (CRM) as a potential driver for niche markets		sustainability-driven compliance
973	Lobbying for industry-wide moves towards sustainable energy sources		sustainability-driven compliance
974	Logistics companies are delayed in sustainability efforts		sustainability-driven compliance
975	Manual processes currently dominate sustainability efforts		sustainability-driven compliance
976	Market need: importance of incorporating new energy sources		sustainability-driven compliance
977	Need for comprehensive tracking and logging of environmental impact		sustainability-driven compliance
978	Need for smarter energy management with new energy sources		sustainability-driven compliance
979	New energy sources: integration of heat pumps and geothermal		sustainability-driven compliance
980	Opportunity for a tech solution to standardize emissions tracking		sustainability-driven compliance
981	Potential for digital twins in sustainability legislation	hackathon	sustainability-driven compliance
982	Recovery rates in battery recycling as an area of focus	hackathon	sustainability-driven compliance
983	Regulatory focus shifts for different projects (FuelForward example)		sustainability-driven compliance
984	Regulatory gap: lack of enforcement for zero-emission zones		sustainability-driven compliance
985	Regulatory influence: mandatory CO2 reporting by suppliers		sustainability-driven compliance
986	Regulatory opportunity: CO2 emission reduction targets		sustainability-driven compliance
987	Rising transport costs due to stricter environmental taxes		sustainability-driven compliance
988	Shift in perception of biomass from positive to negative in sustainability		sustainability-driven compliance
989	Shift towards lower temperature sustainable energy sources		sustainability-driven compliance
990	So if there's regulation, that's a good one. That makes an ideal market, and sustainability is getting there, but companies do everything to avoid doing it really in detail.		sustainability-driven compliance
991	Strategic planning for achieving net-zero across organizational units		sustainability-driven compliance
992	Sustainability as a key challenge and opportunity in supply chains		sustainability-driven compliance
993	Sustainability as a major area of opportunity		sustainability-driven compliance
994	Sustainability compliance as a lucrative market		sustainability-driven compliance
995	Sustainability is a regulation-driven market, but there is still reluctance from companies there		sustainability-driven compliance
996	Sustainability manager: cradle-to-grave emissions visibility, impact areas, multi-stakeholder utility, aiding customers in decision-making		sustainability-driven compliance
997	Taxation as a driving force for reducing emissions		sustainability-driven compliance
998	Tech solutions for compliance and quality checks for suppliers		sustainability-driven compliance
999	Technology's role in improving recycling efficiency	hackathon	sustainability-driven compliance
1000	Unpredictability in sustainability trends and market shifts		sustainability-driven compliance
1001	Volatility of compliance regulations and changing landscape		sustainability-driven compliance
1002	Waarbij ze wel achter de feiten aan lopen over het algemeen.		sustainability-driven compliance
1003	Waste reduction potential		sustainability-driven compliance
1004	Anticipation of future CO2 taxes to enforce sustainability		sustainability-driven compliance
1005	Application focused on terminal design, shift to electric vehicles		sustainability-driven compliance

Operational efficiency through automation

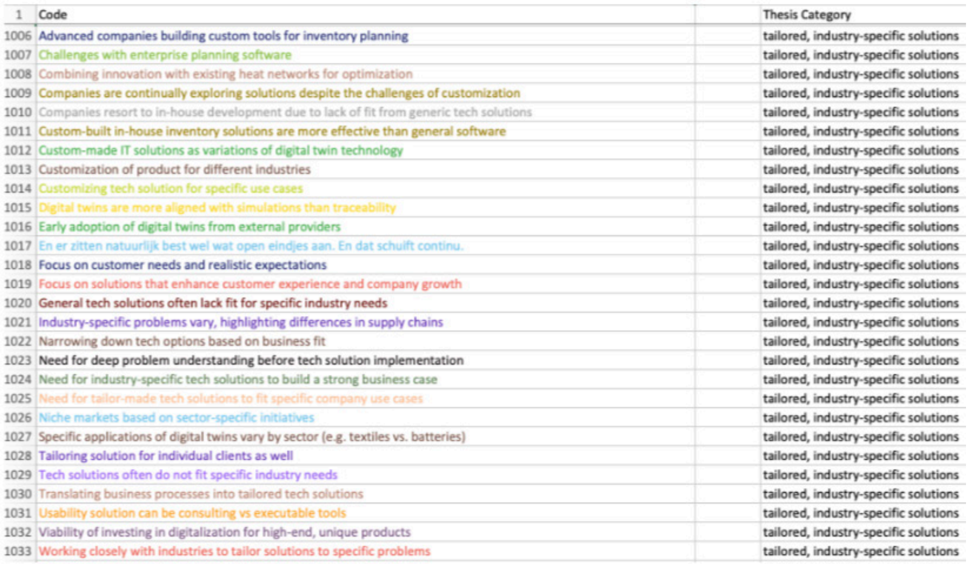
Key insights: Automation and predictive tools are transforming operations by streamlining processes, optimising resource utilisation, and reducing waste. Digital twins have emerged as critical enablers of operational efficiency, offering real-time insights, simulations, and decision-making capabilities. Industries such as logistics, manufacturing, and energy increasingly rely on these tools to enhance process agility, minimise manual interventions, and adapt to disruptions effectively. This operational flexibility has also proven essential in crisis management, where companies use automated systems to respond rapidly to unforeseen challenges.



1	Code		Thesis Category
539	Adding smart algorithms for better decision-making		operational efficiency through automation
540	Airline boarding market: clear problem, consistent consumer base, minimal data dependency, airline efficiency		operational efficiency through automation
541	Application in high frequency tasks and human limitations		operational efficiency through automation
542	Application in inventory planning		operational efficiency through automation
543	Application of digital twin technology in offshore wind farms		operational efficiency through automation
544	Application: anticipated bottleneck in security checkpoints, passport control regulations at Schiphol	hackathon	operational efficiency through automation
545	Application: ASML, dependency plotting, supply chain solution need		operational efficiency through automation
546	Application: baggage hall Schiphol, capacity demand, handling of baggage		operational efficiency through automation
547	Application: charging scheduling with limited infrastructure, optimal charging placement, infra planning		operational efficiency through automation
548	Application: continuous planning with operational adjustments		operational efficiency through automation
549	Application: gate planning inefficiency at Schiphol		operational efficiency through automation
550	Application: Infrastructure shortages in railways in Germany, digital twins can optimize maintenance and identify issues early on		operational efficiency through automation
551	Application: Schiphol, efficiency goals, workforce shortage, dual-sided dependency		operational efficiency through automation
552	Application: support for terminal operations at Maersk		operational efficiency through automation
553	Application: traffic orchestration at Schiphol		operational efficiency through automation
554	Automated gate assignment market: airport-wide optimisation, preventing congestion, eliminating consumers' time buffer,		operational efficiency through automation
555	Automation as a key area for improvement in supply chain processes		operational efficiency through automation
556	Automation limit: 90% success rate with 20% needing manual intervention		operational efficiency through automation
557	Automation potential, information processing		operational efficiency through automation
558	Belief in the future potential of IoT in logistics		operational efficiency through automation
559	Benefit of operational flexibility through higher temperatures		operational efficiency through automation
560	Challenges in supply chain planning and unpredictability in lead times		operational efficiency through automation
561	Combination of solutions: congestion and gate optimisation	hackathon	operational efficiency through automation
562	Complex machinery as a potential driver for digital twin adoption	hackathon	operational efficiency through automation
563	Condition-based maintenance is a popular application	hackathon	operational efficiency through automation
564	Condition-based maintence is good application, because processing sensor data is something machines can and huma	hackathon	operational efficiency through automation
565	Current application of digital twins in factory and production environments	hackathon	operational efficiency through automation
566	Current strength: automation at high-voltage levels	hackathon	operational efficiency through automation
567	Current work: development of algorithms for network investment planning	hackathon	operational efficiency through automation
568	Digital twin application seen more in factories than individual products	hackathon	operational efficiency through automation
569	Digital twin applications in shipping or logistics	hackathon	operational efficiency through automation
570	Digital twins help optimize efficiency, reduce costs, and maximze fleet utilization in shipping	hackathon	operational efficiency through automation
571	Digital twins perceived as valuable for operational monitoring of factories	hackathon	operational efficiency through automation
572	Digital twins potential for operational benefits in wind energy		operational efficiency through automation
573	Digital twins predict maintenance needs, creating a financial obligation		operational efficiency through automation
574	Digital twins recognized as having potential for supply chain improvements		operational efficiency through automation
575	Dual focus: simulating outcomes and simplifying complex processes		operational efficiency through automation
576	Emphasis on inventory management and planning as critical challenges		operational efficiency through automation
577	Example of digital twin tracking inputs in a factory		operational efficiency through automation
578	Example: Alliander experimenting with both simulations and process improvements		operational efficiency through automation
579	Experience in applying digital twins in various sectors		operational efficiency through automation
580	Fruitful market: airplane boarding, automation potential		operational efficiency through automation
581	Fruitful market: airport optimisation		operational efficiency through automation
582	Fruitful market: port congestion		operational efficiency through automation
583	Growing demand for technology in logistics and shipping		operational efficiency through automation
584	Growing trend of digitalization in heating networks		operational efficiency through automation
585	Growth in interest and competition within the heating sector technology		operational efficiency through automation
586	High expectations for temperature optimization using digital twins		operational efficiency through automation
587	Ideal market: Schiphol, complex ecosystem		operational efficiency through automation
588	Increased use of AI-powered robots in warehousing		operational efficiency through automation
589	Industry application: district heating as a use case for digital twins		operational efficiency through automation
590	Inefficiency in planning tools		operational efficiency through automation
591	Interest in companies that address inventory planning challenges in logistics		operational efficiency through automation
592	Inventory planning as a major challenge in supply chain management		operational efficiency through automation
593	Ja, je ziet heel veel digitalisering zoals we noemen in de warmenetten. Waarbij je eerder eigenlijk heel weinig zag.		operational efficiency through automation
594	Key challenge: temperature optimization in heating networks		operational efficiency through automation
595	Key need: focus on optimization		operational efficiency through automation
596	Key opportunity: digital twins providing insights into supplier efficiency		operational efficiency through automation
597	Key value proposition: operational optimization		operational efficiency through automation
598	Limitations of manual processes and the need for automation		operational efficiency through automation
599	Logistics is integral across industries		operational efficiency through automation
600	Maar ik denk dat het met name aan die kant van hoe ontwikkel je nou projecten. Dat daar de grootste innovatie die kans ligt.		operational efficiency through automation
601	Maar je raakt iemands werk en... Ja, op een gegeven moment kun je mensen hun taken uit handen gaan nemen.		operational efficiency through automation
602	Maar tegelijkertijd, het is ook wel absoluut de kant waar we met z'n allen op gaan.		operational efficiency through automation
603	Market opportunity: simualting reality through digital twins		operational efficiency through automation
604	Me: Airplane boarding sequence? Damian: Basically it said that you do it manually. How can something like that not be automate		operational efficiency through automation
605	Multi-layer simulation for future scenario planning		operational efficiency through automation
606	Need for additional expertise in physical tech and automation		operational efficiency through automation
607	Need for internal temperature optimization initiatives alongside regulatory support		operational efficiency through automation
608	Need for predictive tools to manage energy source variability		operational efficiency through automation
609	Opinion that digital twin technologies are best suited for simulations		operational efficiency through automation
610	Opportunities for increased automation with digital twins		operational efficiency through automation
611	Opportunities in robotics and AI for supply chain optimization		operational efficiency through automation
612	Opportunity: digital twins for supply chains to reduce redundant registration		operational efficiency through automation
613	Optimizing temperature for both input and return systems in heating solutions		operational efficiency through automation
614	Port congestion forecasting market: reducing vessel waiting time, data accessibility, vessel movement tracking, simple business c		operational efficiency through automation
615	Potential application at Maersk: complex routing challenges		operational efficiency through automation
616	Potential application at Maersk: focus on their many routine tasks		operational efficiency through automation
617	Potential application at Maersk: high digital maturity		operational efficiency through automation
618	Potential for revenue enhancement through digital twins		operational efficiency through automation
619	Potential of digital twins in both operational and planning phases		operational efficiency through automation
620	Problem solved: unstructured boarding and congestion		operational efficiency through automation
621	Resistance to increasing manual tasks due to automation		operational efficiency through automation
622	Roadblocks encountered in the planning phase of supply chain management		operational efficiency through automation
623	So people do, especially in planning, they do a lot of routine tasks, but they don't see it as routine and they have systems that are		operational efficiency through automation
624	Supply chain optimization as a key offering for industries looking to improve efficiency (e.g. reducing waste or improving material		operational efficiency through automation
625	Supporting customers in inventory planning amidst uncertainties and disruptions		operational efficiency through automation
626	Typical digital twin use case: planning tool		operational efficiency through automation
627	Use case expansion: from operations management		operational efficiency through automation
628	Using digital twins to optimize heat networks		operational efficiency through automation

Tailored, industry-specific solutions

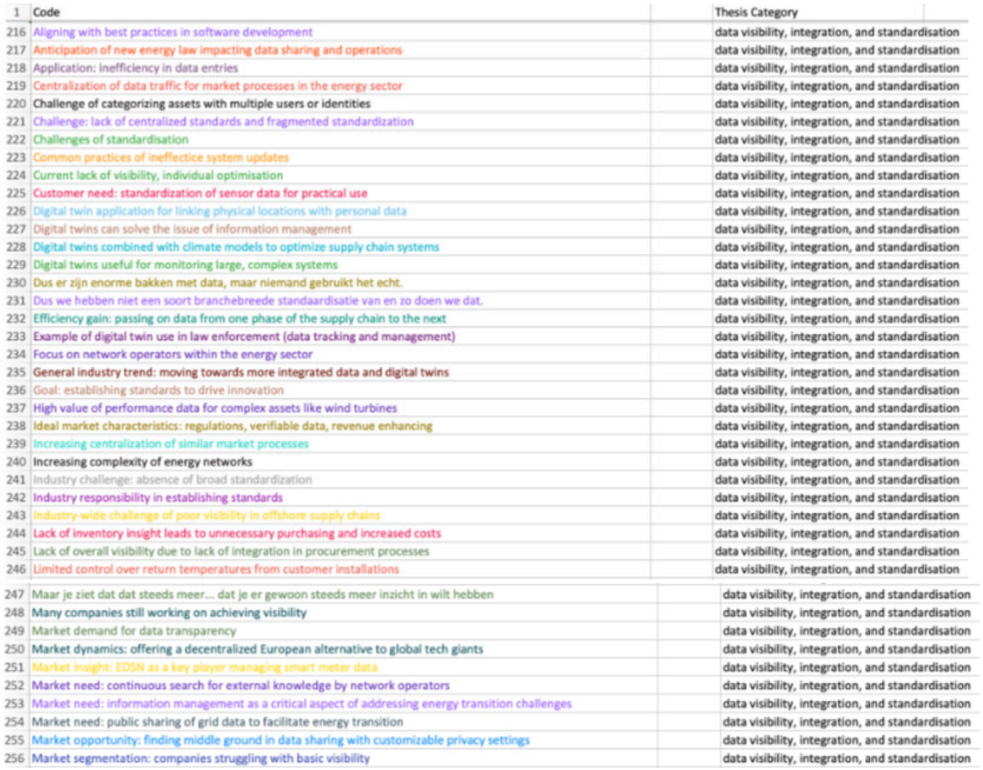
Key insights: A shift toward customised, sector-specific technologies is gaining momentum as businesses demand solutions that address unique operational challenges. Digital twin technology demonstrates value in targeted applications, such as factory management, wind energy, and supply chain logistics, where tailored designs deliver measurable outcomes. Companies are focusing on technologies that align directly with their sustainability strategies, such as eco-design or partial equipment upgrades, to maximise asset lifespans and adapt to industry-specific requirements. This flexibility provides competitive advantages in achieving sustainability goals while addressing market-specific pain points.



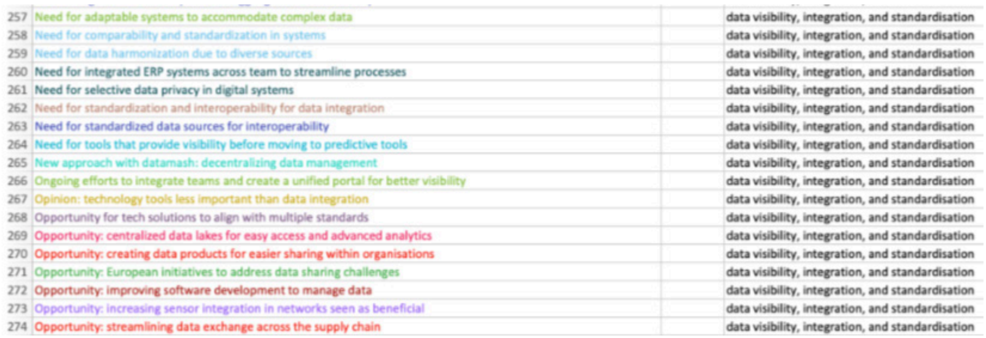
1	Code	Thesis Category
1006	Advanced companies building custom tools for inventory planning	tailored, industry-specific solutions
1007	Challenges with enterprise planning software	tailored, industry-specific solutions
1008	Combining innovation with existing heat networks for optimization	tailored, industry-specific solutions
1009	Companies are continually exploring solutions despite the challenges of customization	tailored, industry-specific solutions
1010	Companies resort to in-house development due to lack of fit from generic tech solutions	tailored, industry-specific solutions
1011	Custom-built in-house inventory solutions are more effective than general software	tailored, industry-specific solutions
1012	Custom-made IT solutions as variations of digital twin technology	tailored, industry-specific solutions
1013	Customization of product for different industries	tailored, industry-specific solutions
1014	Customizing tech solution for specific use cases	tailored, industry-specific solutions
1015	Digital twins are more aligned with simulations than traceability	tailored, industry-specific solutions
1016	Early adoption of digital twins from external providers	tailored, industry-specific solutions
1017	En er zitten natuurlijk best wel wat open eindjes aan. En dat schuift continu.	tailored, industry-specific solutions
1018	Focus on customer needs and realistic expectations	tailored, industry-specific solutions
1019	Focus on solutions that enhance customer experience and company growth	tailored, industry-specific solutions
1020	General tech solutions often lack fit for specific industry needs	tailored, industry-specific solutions
1021	Industry-specific problems vary, highlighting differences in supply chains	tailored, industry-specific solutions
1022	Narrowing down tech options based on business fit	tailored, industry-specific solutions
1023	Need for deep problem understanding before tech solution implementation	tailored, industry-specific solutions
1024	Need for industry-specific tech solutions to build a strong business case	tailored, industry-specific solutions
1025	Need for tailor-made tech solutions to fit specific company use cases	tailored, industry-specific solutions
1026	Niche markets based on sector-specific initiatives	tailored, industry-specific solutions
1027	Specific applications of digital twins vary by sector (e.g. textiles vs. batteries)	tailored, industry-specific solutions
1028	Tailoring solution for individual clients as well	tailored, industry-specific solutions
1029	Tech solutions often do not fit specific industry needs	tailored, industry-specific solutions
1030	Translating business processes into tailored tech solutions	tailored, industry-specific solutions
1031	Usability solution can be consulting vs executable tools	tailored, industry-specific solutions
1032	Viability of investing in digitalization for high-end, unique products	tailored, industry-specific solutions
1033	Working closely with industries to tailor solutions to specific problems	tailored, industry-specific solutions

Data visibility, integration, and standardisation

Key insights: The growing emphasis on data visibility and integration is reshaping the way industries operate. Real-time data tracking, standardised processes, and interoperability are becoming essential for optimising operations and meeting regulatory requirements. Digital twins play an essential role by breaking down data silos and providing holistic views of supply chains and operations. These tools improve decision-making, streamline workflows, and enable more transparent communication among stakeholders. By integrating fragmented data systems, businesses can enable accountability and create unified platforms for managing operations effectively.



1	Code	Thesis Category
216	Aligning with best practices in software development	data visibility, integration, and standardisation
217	Anticipation of new energy law impacting data sharing and operations	data visibility, integration, and standardisation
218	Application: inefficiency in data entries	data visibility, integration, and standardisation
219	Centralization of data traffic for market processes in the energy sector	data visibility, integration, and standardisation
220	Challenge of categorizing assets with multiple users or identities	data visibility, integration, and standardisation
221	Challenge: lack of centralized standards and fragmented standardization	data visibility, integration, and standardisation
222	Challenges of standardisation	data visibility, integration, and standardisation
223	Common practices of ineffectice system updates	data visibility, integration, and standardisation
224	Current lack of visibility, individual optimisation	data visibility, integration, and standardisation
225	Customer need: standardization of sensor data for practical use	data visibility, integration, and standardisation
226	Digital twin application for linking physical locations with personal data	data visibility, integration, and standardisation
227	Digital twins can solve the issue of information management	data visibility, integration, and standardisation
228	Digital twins combined with climate models to optimize supply chain systems	data visibility, integration, and standardisation
229	Digital twins useful for monitoring large, complex systems	data visibility, integration, and standardisation
230	Dus er zijn enorme bakken met data, maar niemand gebruikt het echt.	data visibility, integration, and standardisation
231	Dus we hebben niet een soort branchebreede standaardisatie van en zo doen we dat.	data visibility, integration, and standardisation
232	Efficiency gain: passing on data from one phase of the supply chain to the next	data visibility, integration, and standardisation
233	Example of digital twin use in law enforcement (data tracking and management)	data visibility, integration, and standardisation
234	Focus on network operators within the energy sector	data visibility, integration, and standardisation
235	General industry trend: moving towards more integrated data and digital twins	data visibility, integration, and standardisation
236	Goal: establishing standards to drive innovation	data visibility, integration, and standardisation
237	High value of performance data for complex assets like wind turbines	data visibility, integration, and standardisation
238	Ideal market characteristics: regulations, verifiable data, revenue enhancing	data visibility, integration, and standardisation
239	Increasing centralization of similar market processes	data visibility, integration, and standardisation
240	Increasing complexity of energy networks	data visibility, integration, and standardisation
241	Industry challenge: absence of broad standardization	data visibility, integration, and standardisation
242	Industry responsibility in establishing standards	data visibility, integration, and standardisation
243	Industry-wide challenge of poor visibility in offshore supply chains	data visibility, integration, and standardisation
244	Lack of inventory insight leads to unnecessary purchasing and increased costs	data visibility, integration, and standardisation
245	Lack of overall visibility due to lack of integration in procurement processes	data visibility, integration, and standardisation
246	Limited control over return temperatures from customer installations	data visibility, integration, and standardisation
247	Maar je ziet dat dat steeds meer... dat je er gewoon steeds meer inzicht in wilt hebben	data visibility, integration, and standardisation
248	Many companies still working on achieving visibility	data visibility, integration, and standardisation
249	Market demand for data transparency	data visibility, integration, and standardisation
250	Market dynamics: offering a decentralized European alternative to global tech giants	data visibility, integration, and standardisation
251	Market insight: EDSN as a key player managing smart meter data	data visibility, integration, and standardisation
252	Market need: continuous search for external knowledge by network operators	data visibility, integration, and standardisation
253	Market need: information management as a critical aspect of addressing energy transition challenges	data visibility, integration, and standardisation
254	Market need: public sharing of grid data to facilitate energy transition	data visibility, integration, and standardisation
255	Market opportunity: finding middle ground in data sharing with customizable privacy settings	data visibility, integration, and standardisation
256	Market segmentation: companies struggling with basic visibility	data visibility, integration, and standardisation

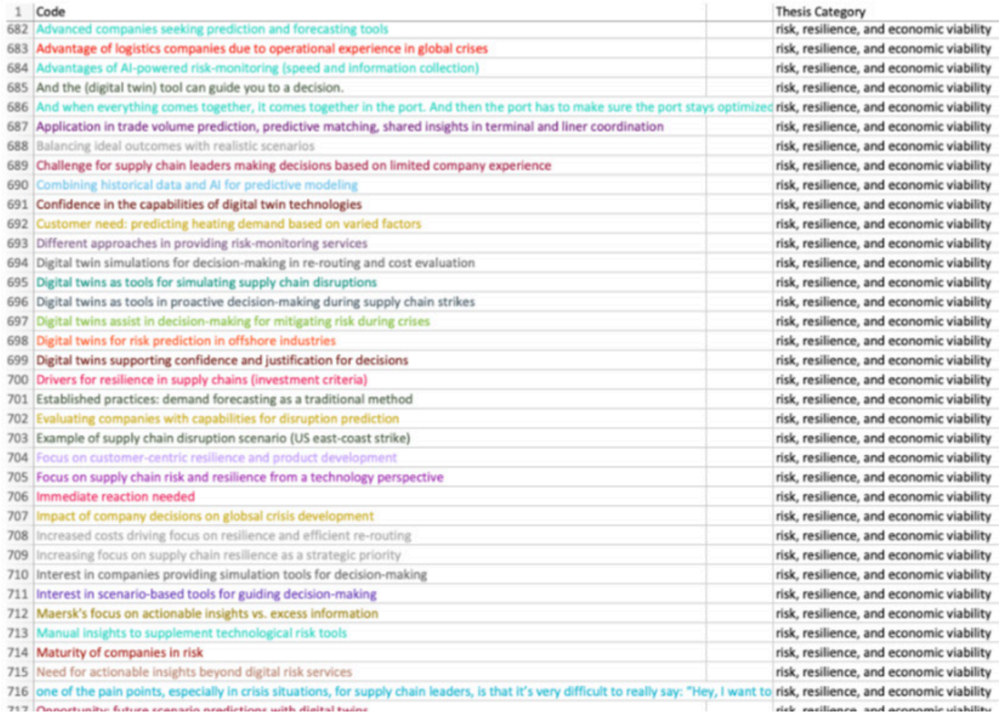


257	Need for adaptable systems to accommodate complex data		data visibility, integration, and standardisation
258	Need for comparability and standardization in systems		data visibility, integration, and standardisation
259	Need for data harmonization due to diverse sources		data visibility, integration, and standardisation
260	Need for integrated ERP systems across team to streamline processes		data visibility, integration, and standardisation
261	Need for selective data privacy in digital systems		data visibility, integration, and standardisation
262	Need for standardization and interoperability for data integration		data visibility, integration, and standardisation
263	Need for standardized data sources for interoperability		data visibility, integration, and standardisation
264	Need for tools that provide visibility before moving to predictive tools		data visibility, integration, and standardisation
265	New approach with datamash: decentralizing data management		data visibility, integration, and standardisation
266	Ongoing efforts to integrate teams and create a unified portal for better visibility		data visibility, integration, and standardisation
267	Opinion: technology tools less important than data integration		data visibility, integration, and standardisation
268	Opportunity for tech solutions to align with multiple standards		data visibility, integration, and standardisation
269	Opportunity: centralized data lakes for easy access and advanced analytics		data visibility, integration, and standardisation
270	Opportunity: creating data products for easier sharing within organisations		data visibility, integration, and standardisation
271	Opportunity: European initiatives to address data sharing challenges		data visibility, integration, and standardisation
272	Opportunity: improving software development to manage data		data visibility, integration, and standardisation
273	Opportunity: increasing sensor integration in networks seen as beneficial		data visibility, integration, and standardisation
274	Opportunity: streamlining data exchange across the supply chain		data visibility, integration, and standardisation

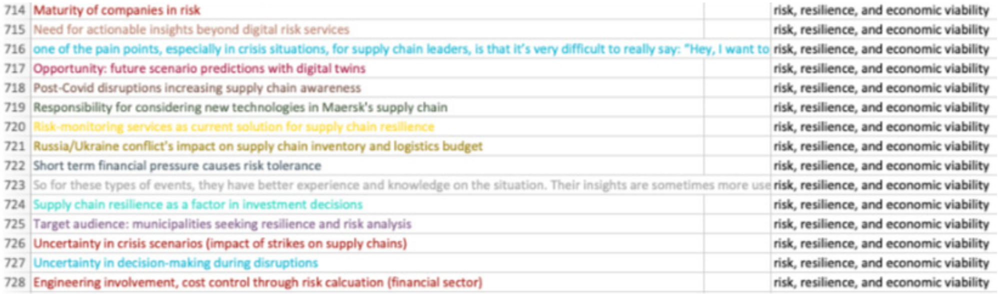
275	Potential for AI to assist in decision-making processes based on data integration	hackathon	data visibility, integration, and standardisation
276	Premium potential from accurate arrival and departure timings		data visibility, integration, and standardisation
277	Prioritizing areas of improvement within the supply chain		data visibility, integration, and standardisation
278	Problem solved: current lack of competitor visibility, limited coordination, individual booking systems		data visibility, integration, and standardisation
279	Real-time data insights for investors		data visibility, integration, and standardisation
280	Real-time data insights for supply chain planners		data visibility, integration, and standardisation
281	Real-time data integration into digital twin models		data visibility, integration, and standardisation
282	Real-time monitoring and responsiveness using digital twins		data visibility, integration, and standardisation
283	Real-time tracking of asset status and emissions		data visibility, integration, and standardisation
284	Real-world challenge of network losses in energy systems		data visibility, integration, and standardisation
285	Reduced downtime through improved response time		data visibility, integration, and standardisation
286	Sector-driven standardization under regulatory pressure		data visibility, integration, and standardisation
287	Simplification of complex processes through digital twins		data visibility, integration, and standardisation
288	Simulation to mirror real-world operations		data visibility, integration, and standardisation
289	Solution through digital twins: predictive modeling for better performance		data visibility, integration, and standardisation
290	Strategic opportunity: aligning with Netbeheer Nederland's digitalization efforts		data visibility, integration, and standardisation
291	Supply chain re-routing decisions in disruption scenarios		data visibility, integration, and standardisation
292	The need for standardization in systems across industries		data visibility, integration, and standardisation
293	Trend: dataspaces as a supportive technology for data sharing across organisations		data visibility, integration, and standardisation
294	Trend: increasing pressure on information management		data visibility, integration, and standardisation
295	Untapped potential in supply chain data		data visibility, integration, and standardisation
296	Use case: training and testing through simulations		data visibility, integration, and standardisation
297	Use of control rooms for operational simulation		data visibility, integration, and standardisation
298	Use of digital twins for remote monitoring of wind turbines		data visibility, integration, and standardisation
299	Use of digital twins to assess assets based on climate risks		data visibility, integration, and standardisation
300	Use of digital twins to optimize temperature regulation in energy transport networks		data visibility, integration, and standardisation
301	Use of linked data processes and collaboration with tech firms		data visibility, integration, and standardisation
302	Use of multiple data sources to build situational awareness		data visibility, integration, and standardisation
303	Value proposition: reducing work by improving data exchange in constrained labor markets		data visibility, integration, and standardisation
304	Assigning identity and managing data for objects in digital twin systems		data visibiltiy, integration, and standardisation
305	Customer need: increased visibility into data		data visibiltiy, integration, and standardisation

Risk, resilience, and economic viability

Key insights: Digital twins have proven instrumental in enhancing risk prediction, crisis management, and resilience in industries with high operational variability, such as offshore energy and logistics. By integrating real-time data and predictive modeling, businesses can better anticipate and mitigate risks while optimising resource allocation. Simultaneously, rising costs in energy and logistics are driving demand for economically viable solutions that demonstrate clear returns on investment. Companies are increasingly adopting technologies that not only reduce costs but also build resilience against supply chain disruptions and regulatory changes, ensuring long-term operational stability.



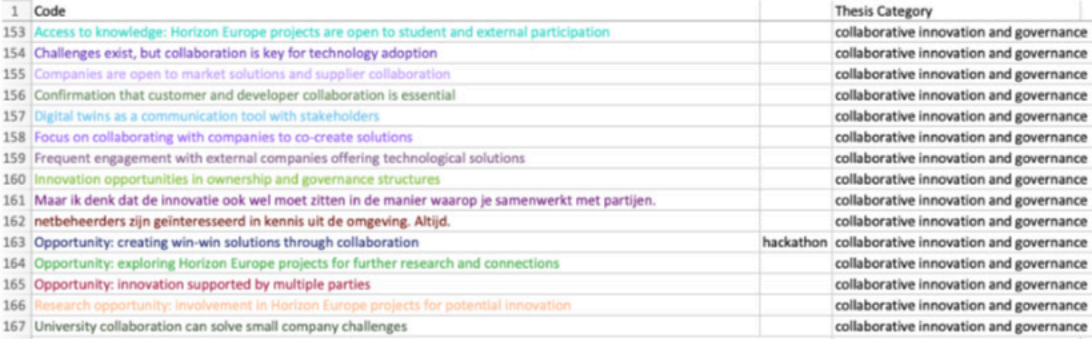
1	Code		Thesis Category
682	Advanced companies seeking prediction and forecasting tools		risk, resilience, and economic viability
683	Advantage of logistics companies due to operational experience in global crises		risk, resilience, and economic viability
684	Advantages of AI-powered risk-monitoring (speed and information collection)		risk, resilience, and economic viability
685	And the (digital twin) tool can guide you to a decision.		risk, resilience, and economic viability
686	And when everything comes together, it comes together in the port. And then the port has to make sure the port stays optimized		risk, resilience, and economic viability
687	Application in trade volume prediction, predictive matching, shared insights in terminal and liner coordination		risk, resilience, and economic viability
688	Balancing ideal outcomes with realistic scenarios		risk, resilience, and economic viability
689	Challenge for supply chain leaders making decisions based on limited company experience		risk, resilience, and economic viability
690	Combining historical data and AI for predictive modeling		risk, resilience, and economic viability
691	Confidence in the capabilities of digital twin technologies		risk, resilience, and economic viability
692	Customer need: predicting heating demand based on varied factors		risk, resilience, and economic viability
693	Different approaches in providing risk-monitoring services		risk, resilience, and economic viability
694	Digital twin simulations for decision-making in re-routing and cost evaluation		risk, resilience, and economic viability
695	Digital twins as tools for simulating supply chain disruptions		risk, resilience, and economic viability
696	Digital twins as tools in proactive decision-making during supply chain strikes		risk, resilience, and economic viability
697	Digital twins assist in decision-making for mitigating risk during crises		risk, resilience, and economic viability
698	Digital twins for risk prediction in offshore industries		risk, resilience, and economic viability
699	Digital twins supporting confidence and justification for decisions		risk, resilience, and economic viability
700	Drivers for resilience in supply chains (investment criteria)		risk, resilience, and economic viability
701	Established practices: demand forecasting as a traditional method		risk, resilience, and economic viability
702	Evaluating companies with capabilities for disruption prediction		risk, resilience, and economic viability
703	Example of supply chain disruption scenario (US east-coast strike)		risk, resilience, and economic viability
704	Focus on customer-centric resilience and product development		risk, resilience, and economic viability
705	Focus on supply chain risk and resilience from a technology perspective		risk, resilience, and economic viability
706	Immediate reaction needed		risk, resilience, and economic viability
707	Impact of company decisions on globsal crisis development		risk, resilience, and economic viability
708	Increased costs driving focus on resilience and efficient re-routing		risk, resilience, and economic viability
709	Increasing focus on supply chain resilience as a strategic priority		risk, resilience, and economic viability
710	Interest in companies providing simulation tools for decision-making		risk, resilience, and economic viability
711	Interest in scenario-based tools for guiding decision-making		risk, resilience, and economic viability
712	Maersk's focus on actionable insights vs. excess information		risk, resilience, and economic viability
713	Manual insights to supplement technological risk tools		risk, resilience, and economic viability
714	Maturity of companies in risk		risk, resilience, and economic viability
715	Need for actionable insights beyond digital risk services		risk, resilience, and economic viability
716	one of the pain points, especially in crisis situations, for supply chain leaders, is that it's very difficult to really say: "Hey, I want to		risk, resilience, and economic viability
717	Opportunity: future scenario predictions with digital twins		risk, resilience, and economic viability



714	Maturity of companies in risk		risk, resilience, and economic viability
715	Need for actionable insights beyond digital risk services		risk, resilience, and economic viability
716	one of the pain points, especially in crisis situations, for supply chain leaders, is that it's very difficult to really say: "Hey, I want to		risk, resilience, and economic viability
717	Opportunity: future scenario predictions with digital twins		risk, resilience, and economic viability
718	Post-Covid disruptions increasing supply chain awareness		risk, resilience, and economic viability
719	Responsibility for considering new technologies in Maersk's supply chain		risk, resilience, and economic viability
720	Risk-monitoring services as current solution for supply chain resilience		risk, resilience, and economic viability
721	Russia/Ukraine conflict's impact on supply chain inventory and logistics budget		risk, resilience, and economic viability
722	Short term financial pressure causes risk tolerance		risk, resilience, and economic viability
723	So for these types of events, they have better experience and knowledge on the situation. Their insights are sometimes more use		risk, resilience, and economic viability
724	Supply chain resilience as a factor in investment decisions		risk, resilience, and economic viability
725	Target audience: municipalities seeking resilience and risk analysis		risk, resilience, and economic viability
726	Uncertainty in crisis scenarios (impact of strikes on supply chains)		risk, resilience, and economic viability
727	Uncertainty in decision-making during disruptions		risk, resilience, and economic viability
728	Engineering involvement, cost control through risk calcuation (financial sector)		risk, resilience, and economic viability

Collaborative innovation and governance

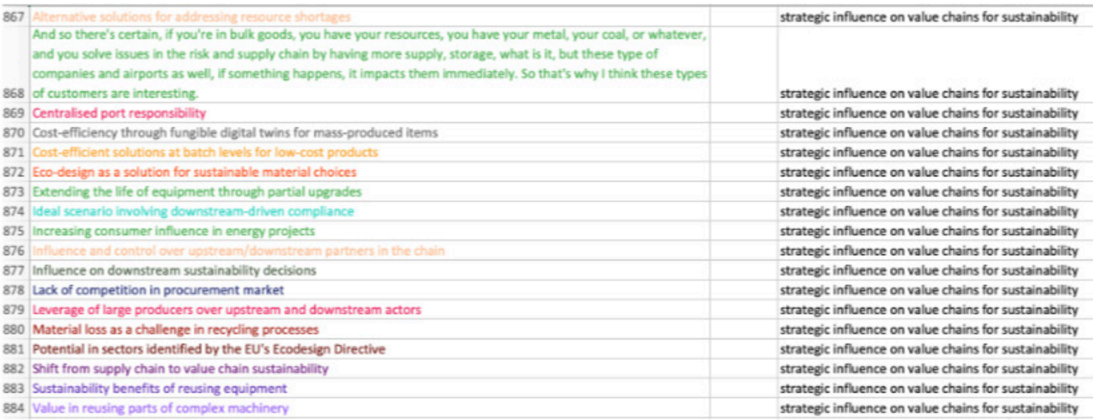
Key insights: Opportunities lie in enabling collaborative governance, shared platforms, and cross-industry innovation. Flexible governance frameworks are crucial for addressing challenges like data standardisation, regulatory compliance, and innovation. By encouraging collective efforts across supply chains and industries, businesses can overcome fragmented stakeholder dynamics and accelerate the adoption of transformative technologies. Collaboration is particularly essential in sectors where multiple stakeholders must align to achieve sustainability and efficiency goals.



1	Code		Thesis Category
153	Access to knowledge: Horizon Europe projects are open to student and external participation		collaborative innovation and governance
154	Challenges exist, but collaboration is key for technology adoption		collaborative innovation and governance
155	Companies are open to market solutions and supplier collaboration		collaborative innovation and governance
156	Confirmation that customer and developer collaboration is essential		collaborative innovation and governance
157	Digital twins as a communication tool with stakeholders		collaborative innovation and governance
158	Focus on collaborating with companies to co-create solutions		collaborative innovation and governance
159	Frequent engagement with external companies offering technological solutions		collaborative innovation and governance
160	Innovation opportunities in ownership and governance structures		collaborative innovation and governance
161	Maar ik denk dat de innovatie ook wel moet zitten in de manier waarop je samenwerkt met partijen.		collaborative innovation and governance
162	netbeheerders zijn geïnteresseerd in kennis uit de omgeving. Altijd.		collaborative innovation and governance
163	Opportunity: creating win-win solutions through collaboration	hackathon	collaborative innovation and governance
164	Opportunity: exploring Horizon Europe projects for further research and connections		collaborative innovation and governance
165	Opportunity: innovation supported by multiple parties		collaborative innovation and governance
166	Research opportunity: involvement in Horizon Europe projects for potential innovation		collaborative innovation and governance
167	University collaboration can solve small company challenges		collaborative innovation and governance

Strategic influence on value chains for sustainability

Key insights: The growing focus on sustainability has expanded beyond traditional supply chains to include the entire value chains. Companies are shifting their attention upstream to ensure sustainable practices in material sourcing and addressing Scope 3 emissions. Digital twin technologies and other advanced tools enable businesses to enhance visibility and accountability across the value chain, helping them align with sustainability goals. This holistic approach differentiates companies by ensuring eco-friendly practices and building resilience throughout the value chain.



867	Alternative solutions for addressing resource shortages		strategic influence on value chains for sustainability
868	And so there's certain, if you're in bulk goods, you have your resources, you have your metal, your coal, or whatever, and you solve issues in the risk and supply chain by having more supply, storage, what is it, but these type of companies and airports as well, if something happens, it impacts them immediately. So that's why I think these types of customers are interesting.		strategic influence on value chains for sustainability
869	Centralised port responsibility		strategic influence on value chains for sustainability
870	Cost-efficiency through fungible digital twins for mass-produced items		strategic influence on value chains for sustainability
871	Cost-efficient solutions at batch levels for low-cost products		strategic influence on value chains for sustainability
872	Eco-design as a solution for sustainable material choices		strategic influence on value chains for sustainability
873	Extending the life of equipment through partial upgrades		strategic influence on value chains for sustainability
874	Ideal scenario involving downstream-driven compliance		strategic influence on value chains for sustainability
875	Increasing consumer influence in energy projects		strategic influence on value chains for sustainability
876	Influence and control over upstream/downstream partners in the chain		strategic influence on value chains for sustainability
877	Influence on downstream sustainability decisions		strategic influence on value chains for sustainability
878	Lack of competition in procurement market		strategic influence on value chains for sustainability
879	Leverage of large producers over upstream and downstream actors		strategic influence on value chains for sustainability
880	Material loss as a challenge in recycling processes		strategic influence on value chains for sustainability
881	Potential in sectors identified by the EU's Ecodesign Directive		strategic influence on value chains for sustainability
882	Shift from supply chain to value chain sustainability		strategic influence on value chains for sustainability
883	Sustainability benefits of reusing equipment		strategic influence on value chains for sustainability
884	Value in reusing parts of complex machinery		strategic influence on value chains for sustainability

Traceability, transparency, and fraud prevention in supply chains

Key insights: Traceability and transparency have become non-negotiable for achieving full supply chain visibility. Digital twin technology and blockchain solutions provide essential capabilities for tracking physical goods, auditing processes, and ensuring compliance with accountability standards. Moreover, businesses are increasingly investing in fraud-proof systems to guarantee the authenticity and security of supply chain data. These systems play a critical role in meeting regulatory requirements and enabling customer trust, especially in industries reliant on high levels of accountability.

1	Code		Thesis Category
1082	Application: dependency knowledge gap at MoD		traceability, transparency, and fraud prevention in supply chains
1083	Application: energy heat map idea, overcapacity management, energy consumption transparency		traceability, transparency, and fraud prevention in supply chains
1084	Application: energy market has over/underproduction consequences		traceability, transparency, and fraud prevention in supply chains
1085	Application: imited knowledge of lower tiers in complex supply chains		traceability, transparency, and fraud prevention in supply chains
1086	Application: nvestment-driven transparency		traceability, transparency, and fraud prevention in supply chains
1087	Application: transparency demand in complex supply chains		traceability, transparency, and fraud prevention in supply chains
1088	Auditability as an importance feature in blockchain-based solutions		traceability, transparency, and fraud prevention in supply chains
1089	Challenge of tracking financial, goods, and data flows in supply chains		traceability, transparency, and fraud prevention in supply chains
1090	Container tracking as a potential use case for digital twins		traceability, transparency, and fraud prevention in supply chains
	Damian on Schiphol belts: I think this is going to be a serious problem if it's not tackled now. And I think this will definitely affect almost anyone who's struggling for business.		
1091	Silvia: I think I need a solution.	hackathon	traceability, transparency, and fraud prevention in supply chains
1092	Detailed example of supply chain transparency issues in fishing industry	hackathon	traceability, transparency, and fraud prevention in supply chains
1093	Digital twins as a tool for transparency in community relations	hackathon	traceability, transparency, and fraud prevention in supply chains
1094	Digital twins provide transparency and enhanced visualization	hackathon	traceability, transparency, and fraud prevention in supply chains
1095	Dutch Ministry has a lot of money available for these initiatives		traceability, transparency, and fraud prevention in supply chains
1096	Eletric vehicle market: large market pool, complex supply chains, consumer tangibility, transparency need, financial and regulatory drivers		traceability, transparency, and fraud prevention in supply chains
1097	Ensuring full transparency at the shipment level		traceability, transparency, and fraud prevention in supply chains
1098	Example of global logistics and traceability using blockchain		traceability, transparency, and fraud prevention in supply chains
1099	Example of supply chain control tower for real-time visiblity (Nike)		traceability, transparency, and fraud prevention in supply chains
1100	Example of textile track-and-trace technology (A-Ware)		traceability, transparency, and fraud prevention in supply chains
1101	Expertise and insights from logistics companies to guide supply chain decisions		traceability, transparency, and fraud prevention in supply chains
1102	Forecasting future capacity needs due to increasing demand (e.g. electric vehicles)		traceability, transparency, and fraud prevention in supply chains
1103	Fruitful market: healthcare		traceability, transparency, and fraud prevention in supply chains
1104	Fruitful market: modeling of dependencies, scalable solution		traceability, transparency, and fraud prevention in supply chains
1105	Gaining better visibility in logistics and transportation		traceability, transparency, and fraud prevention in supply chains
1106	Healthcare market: regulation and resource needs, robotics integration		traceability, transparency, and fraud prevention in supply chains
1107	Het is niet langer gewoon een getalletje, maar het komt echt tot leven.		traceability, transparency, and fraud prevention in supply chains
1108	Ideal market characteristic: complex supply chains		traceability, transparency, and fraud prevention in supply chains
1109	Ideal market characteristic: fast-changing conditions		traceability, transparency, and fraud prevention in supply chains
1110	Ideal market: MoD, money enough		traceability, transparency, and fraud prevention in supply chains
1111	Ideal market: resource heavy industries, high impact customers, resource dependency		traceability, transparency, and fraud prevention in supply chains
1112	Identifying supply chain vulnerabilities to climate risks		traceability, transparency, and fraud prevention in supply chains
1113	Importance of digital twins for tracking physical objects across processes		traceability, transparency, and fraud prevention in supply chains
1114	Increased value of traceable products in the marketplace		traceability, transparency, and fraud prevention in supply chains
1115	Increased willingness to pay for fraud-proof systems		traceability, transparency, and fraud prevention in supply chains
1116	Lack of knowledge on equipment location as a supply chain challenge		traceability, transparency, and fraud prevention in supply chains
1117	Link between track-and-trace technology and digital product passports		traceability, transparency, and fraud prevention in supply chains
1118	Maar je wilt bijvoorbeeld wel dat je het kan auditen.		traceability, transparency, and fraud prevention in supply chains
1119	Mass balance as a method to ensure traceability and transparency		traceability, transparency, and fraud prevention in supply chains
1120	Military and ministries of defense, there's absolutely no shortage of money in the NATO countries. So the Netherlands alone are spending 8 billion euros more this year. And they need to understand their dependencies.		traceability, transparency, and fraud prevention in supply chains
1121	Military drone application solves the unclear business case		traceability, transparency, and fraud prevention in supply chains
1122	Military drone procurement market: rapid production scaling challenge, knowledge needed for rapid innovation in supply chain		traceability, transparency, and fraud prevention in supply chains
1123	MoD market: urgent transformation, unlimited budget, collaboration with Dutch initiatives, sovereignty drive		traceability, transparency, and fraud prevention in supply chains
1124	Need for fraud prevention in supply chains		traceability, transparency, and fraud prevention in supply chains
1125	Need to relate objects, locations, and stakeholders in complex systems		traceability, transparency, and fraud prevention in supply chains
1126	Opportunities for low-cost, mobile solutions for supply chain transparency		traceability, transparency, and fraud prevention in supply chains
1127	Opportunity: using predictive models for energy consumption		traceability, transparency, and fraud prevention in supply chains
1128	Perceived value of digital traceability for high-cost goods		traceability, transparency, and fraud prevention in supply chains
1129	Physical integration of digital tracking within fibers		traceability, transparency, and fraud prevention in supply chains
1130	Physical traceability as essential for full transparency		traceability, transparency, and fraud prevention in supply chains
1131	Potential niche markets in agriculture (e.g. fruit, chocolate)	hackathon	traceability, transparency, and fraud prevention in supply chains
1132	Progressive companies are early adopters	hackathon	traceability, transparency, and fraud prevention in supply chains
1133	Recognition of NexTwin's potential in transparency and traceability debates	hackathon	traceability, transparency, and fraud prevention in supply chains
1134	Skepticism about the transparency aspect of digital twin technology		traceability, transparency, and fraud prevention in supply chains
1135	So if somebody could model the supply chain of the economy and show where the dependencies are, you can get a certain player in the ecosystem. That's really interesting.		traceability, transparency, and fraud prevention in supply chains
1136	Tracking at shipment/batch level for efficiency		traceability, transparency, and fraud prevention in supply chains
1137	Tracking data, money, and goods flows through blockchain		traceability, transparency, and fraud prevention in supply chains
1138	Transparency need in food/agriculture, fashion, pharma		traceability, transparency, and fraud prevention in supply chains
1139	Use of affordable technologies like QR codes for tracking and transparency		traceability, transparency, and fraud prevention in supply chains
1140	Use of automation in digital twins to track materials in real-time		traceability, transparency, and fraud prevention in supply chains
1141	Use of traceable products to meet sustainability and social impact goals		traceability, transparency, and fraud prevention in supply chains
1142	Value proposition of digital twins in ensuring transparency and preventing fraud		traceability, transparency, and fraud prevention in supply chains
1143	Visibility enhancement		traceability, transparency, and fraud prevention in supply chains
1144	Vulnerability visibility supply chain market for NATO	hackathon	traceability, transparency, and fraud prevention in supply chains

D. Hackathon Materials and Visual Outputs

This appendix includes key materials and visual outputs from the Reverse Hackathon session. It features the workshop invitation sent to participants, digitalised whiteboards with sticky notes capturing insights from the session, and a selection of photos taken during the event. The photos include moments from individual and group dicussions, as well as a snapshot of the facilitator (myself) alongside the filled whiteboard wall that summarised the co-creation outcomes.

Reverse Hackathon Workshop Invitation

Friday, November 1, 2024
13:00 - 16:00
Location: Docklab, Vasteland 100, Rotterdam
(3rd floor)

This Reverse Hackathon workshop is focused on identifying the best market application for NexTwin's digital twin technology. We'll use different perspectives from industry experts in collaborative thought experiments to align NexTwin's capabilities with real-world market demands.

Workshop Objectives:

- **Define a suitable problem and market for NexTwin**
- **Engage in collaborative thought experiments**
- **Gain some new industry insights**

Workshop Agenda:

12:45 - 13:00	Walk-in
13:00 - 13:15	Introduction & Context Setting
13:15 - 13:35	Obstacle Review
13:35 - 14:10	Thought Experiment 1
14:10 - 14:45	Thought Experiment 2
14:45 - 15:00	Break
15:00 - 15:30	Thought Experiment 3
15:30 - 16:00	Prioritizing Exercise
16:00	Closing

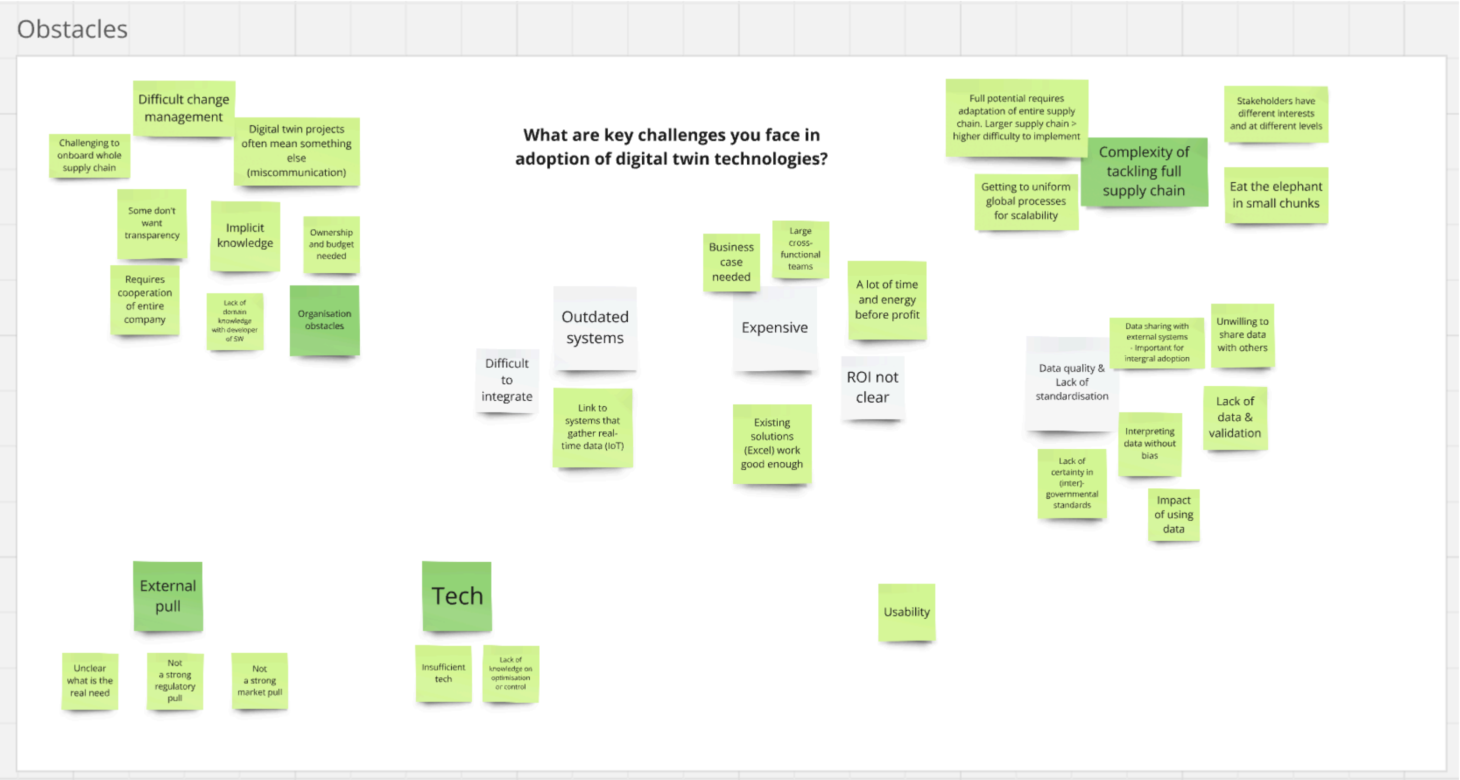
Your Role and Preparation
Minimal preparation is needed, with familiarity with current trends in digital twins and/or your industry or supply chain will be beneficial. I'm looking forward to an engaging session where your insights will be instrumental in defining a strong market fit for NexTwin.

Please confirm your participation by replying to this email.

Kind regards,
Zora Schiferli
MSc Strategic Design at TU Delft
Graduate Student at Docklab

+31 6 365577280

NEXTWIN
by DOCKLAB



Obstacles

What are key challenges you face in adoption of digital twin technologies?

Difficult change management

Challenging to onboard whole supply chain

Digital twin projects often mean something else (miscommunication)

Some don't want transparency

Implicit knowledge

Ownership and budget needed

Requires cooperation of entire company

Lack of domain knowledge with developer of SW

Organisation obstacles

Outdated systems

Difficult to integrate

Link to systems that gather real-time data (IoT)

Business case needed

Large cross-functional teams

Expensive

A lot of time and energy before profit

ROI not clear

Existing solutions (Excel) work good enough

Full potential requires adaptation of entire supply chain. Larger supply chain > higher difficulty to implement

Complexity of tackling full supply chain

Getting to uniform global processes for scalability

Stakeholders have different interests and at different levels

Eat the elephant in small chunks

Data quality & Lack of standardisation

Data sharing with external systems - Important for intergral adoption

Unwilling to share data with others

Lack of data & validation

Interpreting data without bias

Lack of certainty in (inter)-governmental standards

Impact of using data

External pull

Unclear what is the real need

Not a strong regulatory pull

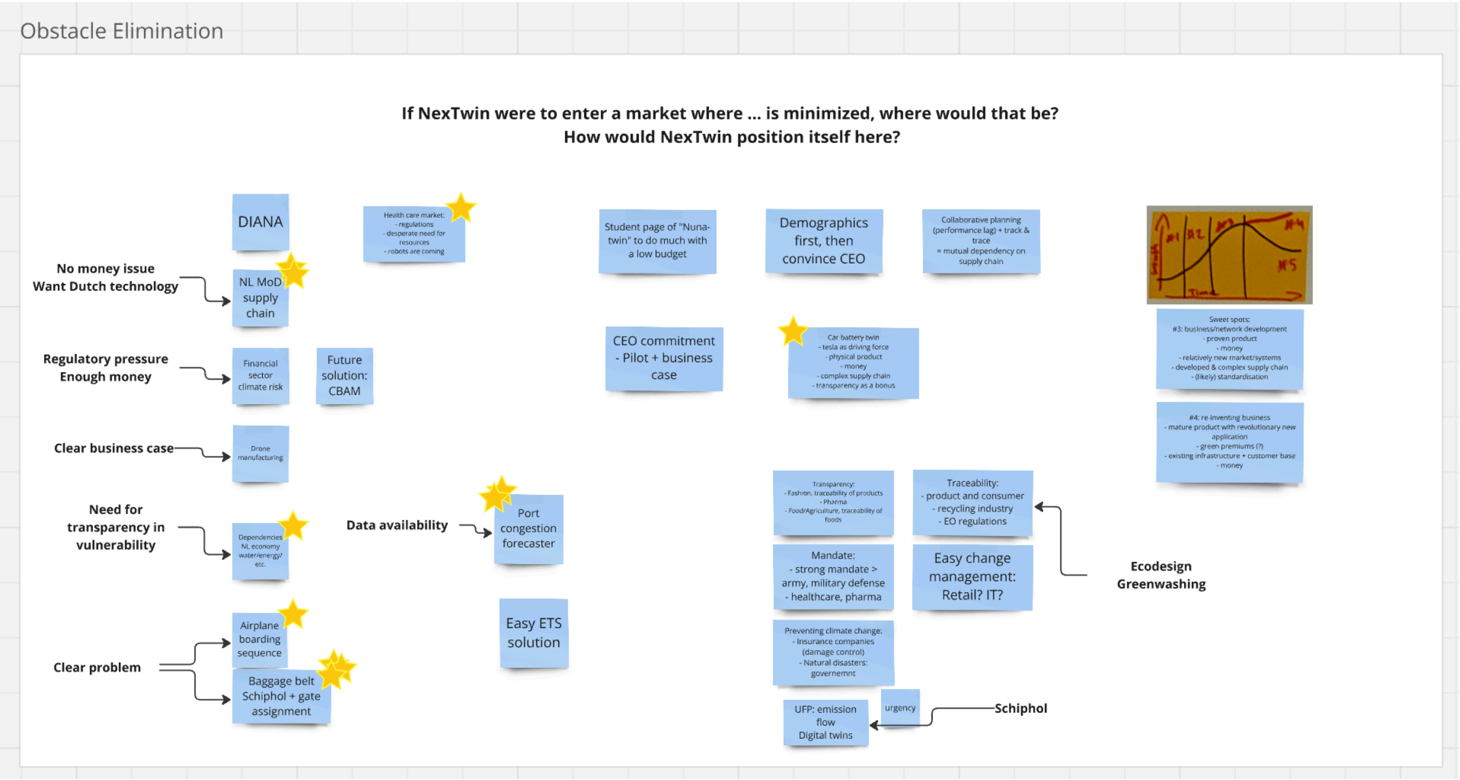
Not a strong market pull

Tech

Insufficient tech

Lack of knowledge on optimisation or control

Usability



Obstacle Elimination

If NexTwin were to enter a market where ... is minimized, where would that be?
How would NexTwin position itself here?

DIANA

No money issue
Want Dutch technology → NL MoD supply chain

Regulatory pressure
Enough money → Financial sector climate risk

Future solution: CBAM

Clear business case → Drone manufacturing

Need for transparency in vulnerability → Dependencies NL economy water/energy/ etc.

Clear problem → Airplane boarding sequence; Baggage belt Schiphol + gate assignment

Health care market:
- regulations
- desperate need for resources
- robots are coming

Data availability → Port congestion forecaster

Easy ETS solution

Student page of "Nuna-twin" to do much with a low budget

Demographics first, then convince CEO

Collaborative planning (performance lag) + track & trace
= mutual dependency on supply chain

CEO commitment
- Pilot + business case

Car battery twin
- tesla as driving force
- physical product
- money
- complex supply chain
- transparency as a bonus

Transparency:
- Fashion, traceability of products
- Pharma
- Food/Agriculture, traceability of foods

Traceability:
- product and consumer
- recycling industry
- EO regulations

Mandate:
- strong mandate > army, military defense
- healthcare, pharma

Easy change management: Retail? IT?

Ecodesign
Greenwashing → Traceability

Preventing climate change:
- Insurance companies (damage control)
- Natural disasters: governemnt

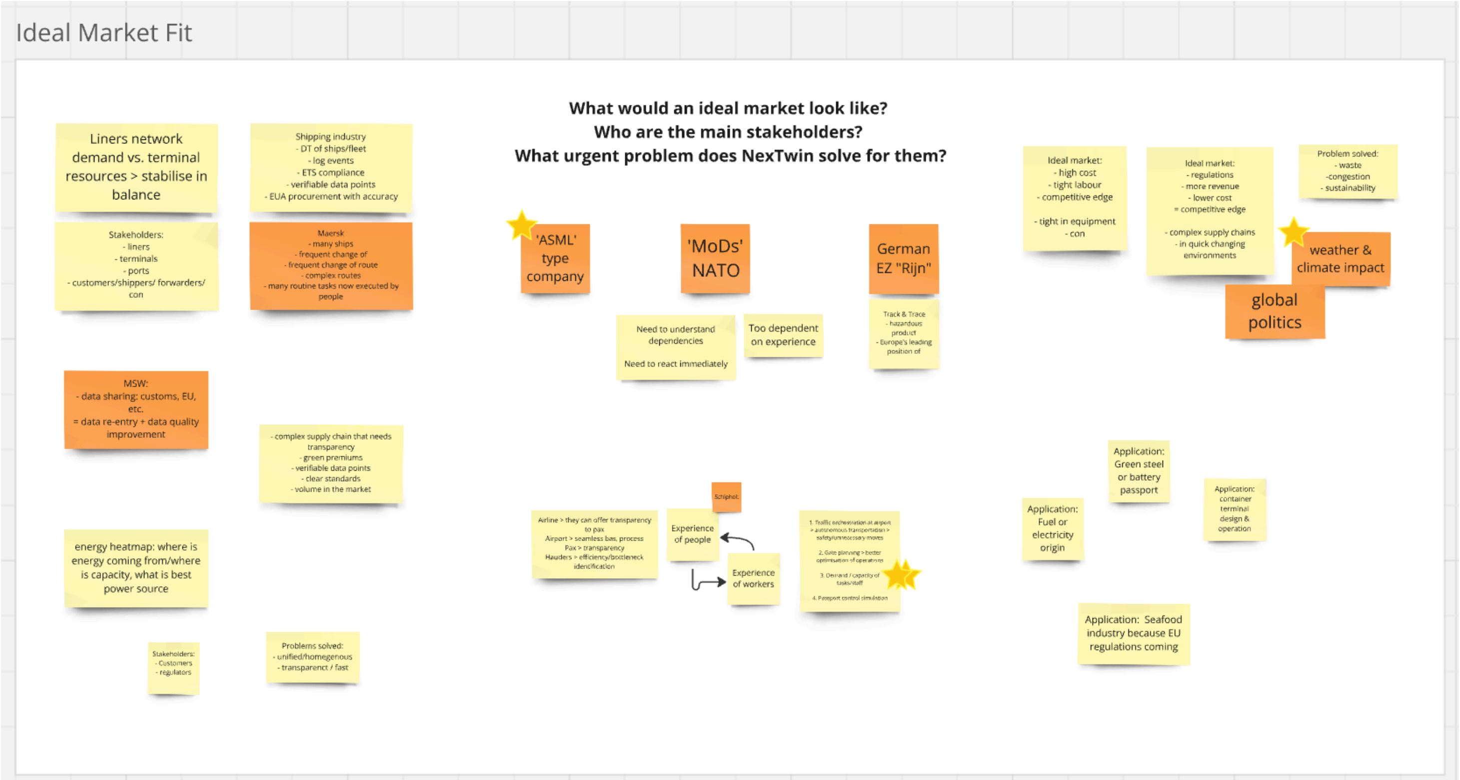
UFP: emission flow
Digital twins

urgency

Schiphol → UFP: emission flow Digital twins

Sweet spots:
#3: business/network development
- proven product
- money
- relatively new market/systems
- developed & complex supply chain
- (likely) standardisation

#4: re-inventing business
- mature product with revolutionary new application
- green premiums (?)
- existing infrastructure + customer base
- money



Ideal Market Fit

What would an ideal market look like?
Who are the main stakeholders?
What urgent problem does NexTwin solve for them?

Liners network demand vs. terminal resources > stabilise in balance

Shipping industry
- DT of ships/fleet
- log events
- ETS compliance
- verifiable data points
- EUA procurement with accuracy

Stakeholders:
- liners
- terminals
- ports
- customers/shippers/ forwarders/ con

Maersk
- many ships
- frequent change of
- frequent change of route
- complex routes
- many routine tasks now executed by people

MSW:
- data sharing: customs, EU, etc.
= data re-entry + data quality improvement

- complex supply chain that needs transparency
- green premiums
- verifiable data points
- clear standards
- volume in the market

energy heatmap: where is energy coming from/where is capacity, what is best power source

Stakeholders:
- Customers
- regulators

Problems solved:
- unified/homegenous
- transparenct / fast

'ASML' type company

'MoDs' NATO

Need to understand dependencies

Need to react immediately

Too dependent on experience

German EZ "Rijn"

Track & Trace
- hazardous product
- Europe's leading position of

Schiphol:

Airline > they can offer transparency to pax
Airport > seamless bas, process
Pax > transparency
Hauders > efficiency/bottleneck identification

Experience of people

Experience of workers

1. Traffic orchestration at airport > autonomous transportation > safety/unnecessary moves

2. Gate planning > better optimisation of operations

3. Demand / capacity of tasks/staff

4. Passport control simulation

Ideal market:
- high cost
- tight labour
- competitive edge

- tight in equipment
- con

Ideal market:
- regulations
- more revenue
- lower cost
= competitive edge

- complex supply chains
- in quick changing environments

Problem solved:
- waste
-congestion
- sustainability

weather & climate impact

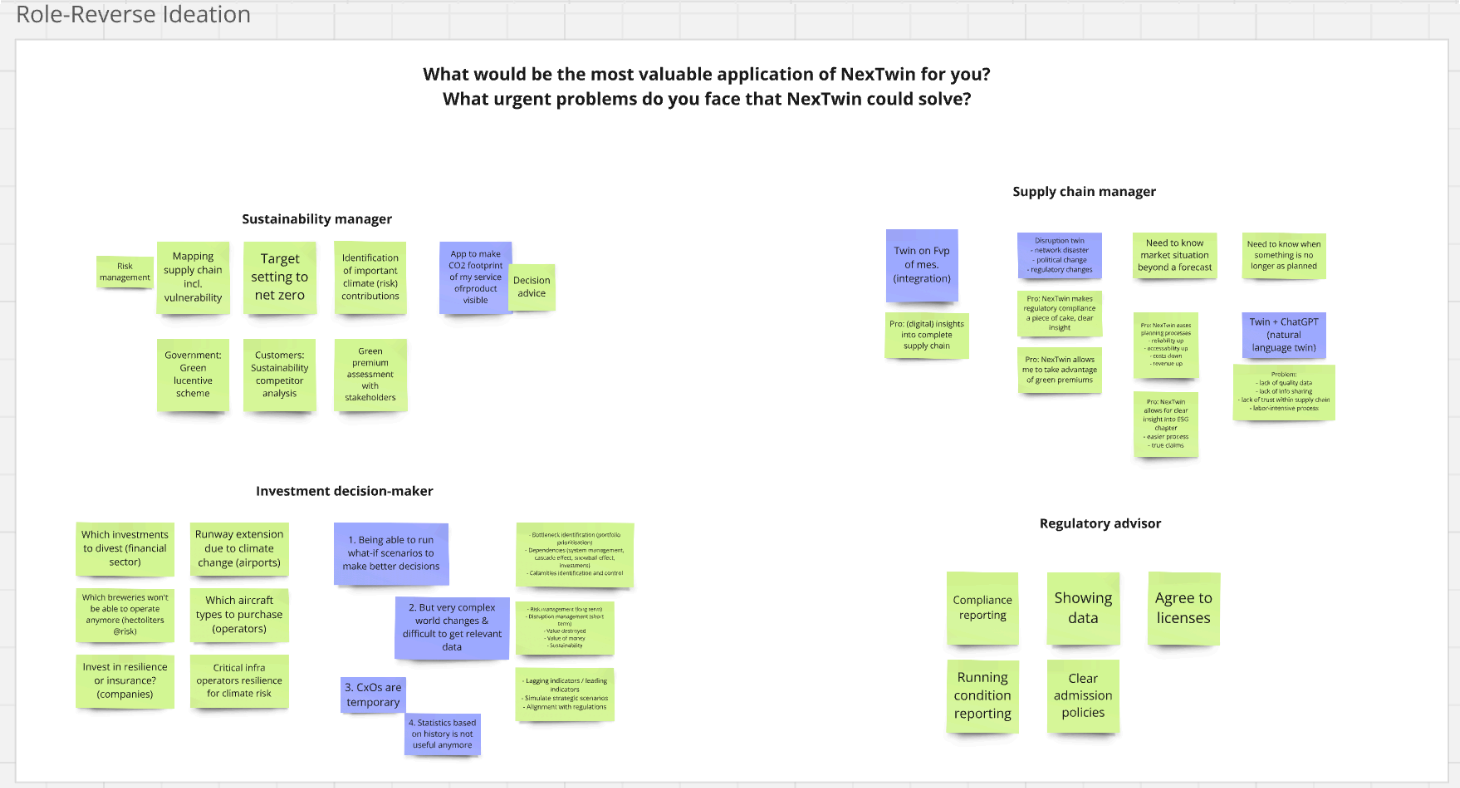
global politics

Application: Green steel or battery passport

Application: Fuel or electricity origin

Application: container terminal design & operation

Application: Seafood industry because EU regulations coming



Role-Reverse Ideation

What would be the most valuable application of NexTwin for you?
What urgent problems do you face that NexTwin could solve?

Sustainability manager

Risk management

Mapping supply chain incl. vulnerability

Target setting to net zero

Identification of important climate (risk) contributions

App to make CO2 footprint of my service ofrproduct visible

Decision advice

Government: Green lucentive scheme

Customers: Sustainability competitor analysis

Green premium assessment with stakeholders

Investment decision-maker

Which investments to divest (financial sector)

Runway extension due to climate change (airports)

Which breweries won't be able to operate anymore (hectoliters @risk)

Which aircraft types to purchase (operators)

Invest in resilience or insurance? (companies)

Critical infra operators resilience for climate risk

1. Being able to run what-if scenarios to make better decisions

2. But very complex world changes & difficult to get relevant data

3. CxOs are temporary

4. Statistics based on history is not useful anymore

- Bottleneck identification (portfolio prioritisation)
- Dependencies (system management, cascade effect, snowball effect, investments)
- Calamities identification and control

- Risk management (long term)
- Disruption management (short term)
- Value destroyed
- Value of money
- Sustainability

- Lagging indicators / leading indicators
- Simulate strategic scenarios
- Alignment with regulations

Supply chain manager

Twin on Fvp of mes. (integration)

Pro: (digital) insights into complete supply chain

Disruption twin
- network disaster
- political change
- regulatory changes

Pro: NexTwin makes regulatory compliance a piece of cake, clear insight

Pro: NexTwin allows me to take advantage of green premiums

Need to know market situation beyond a forecast

Pro: NexTwin eases planning processes
- reliability up
- accessability up
- costs down
- revenue up

Pro: NexTwin allows for clear insight into ESG chapter
- easier process
- true claims

Need to know when something is no longer as planned

Twin + ChatGPT (natural language twin)

Problem:
- lack of quality data
- lack of info sharing
- lack of trust within supply chain
- labor-intensive process

Regulatory advisor

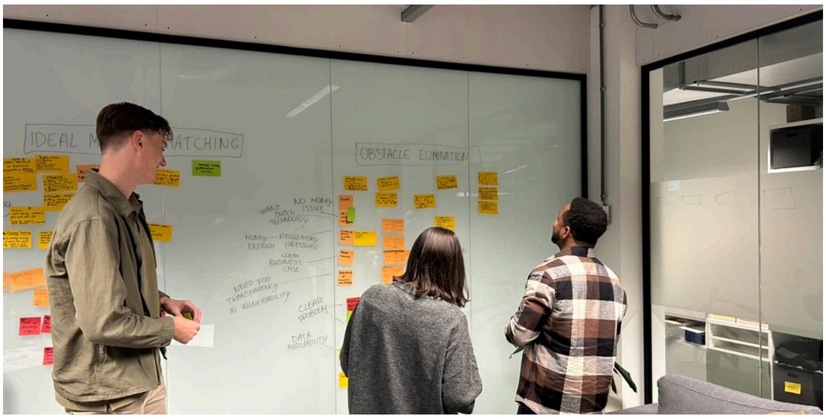
Compliance reporting

Showing data

Agree to licenses

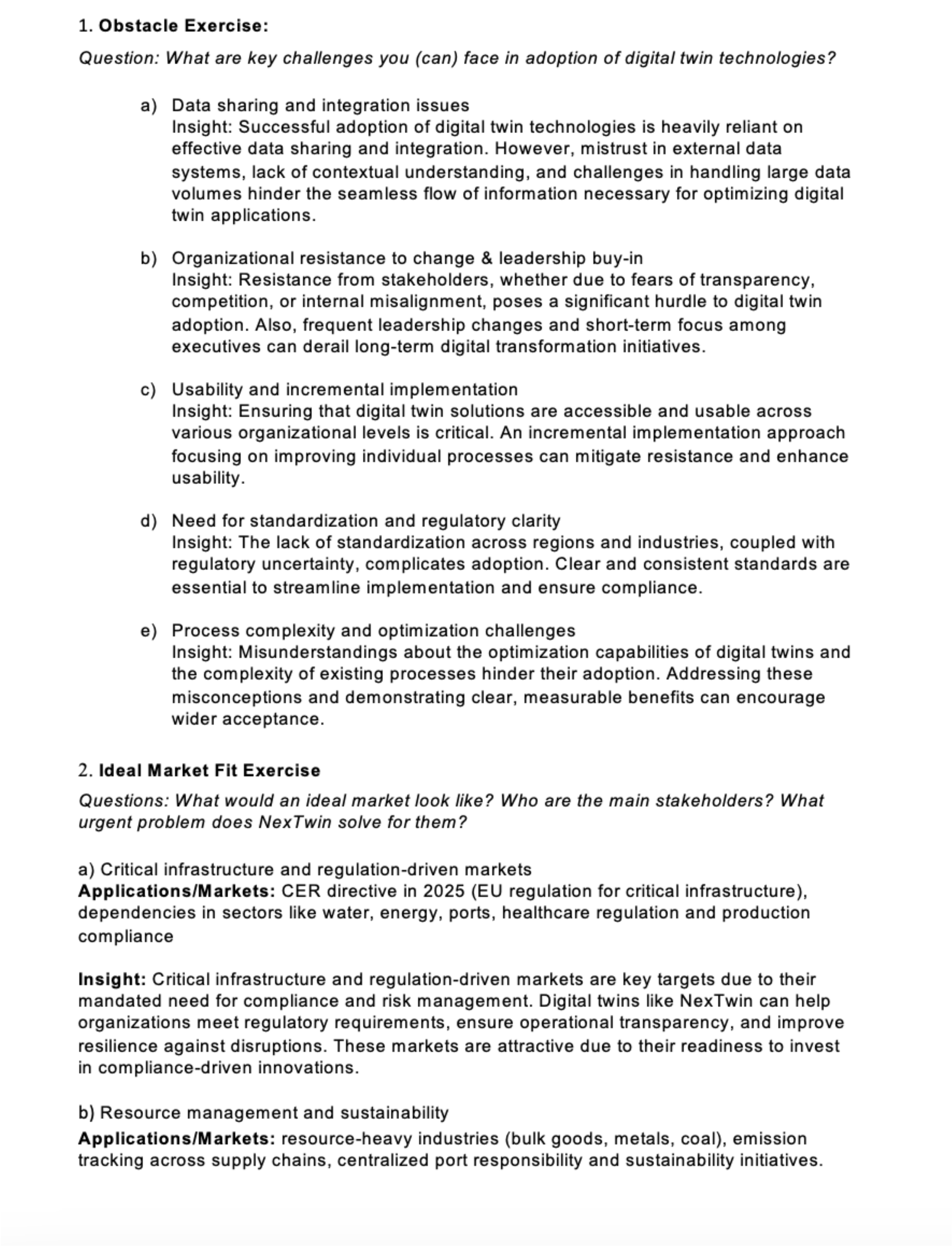
Running condition reporting

Clear admission policies



E. Hackathon Insights

This appendix includes the summarised insights from the Reverse Hackathon, based on the transcripts and the visual outputs of the session. These summarised insights were also sent to the participants after the session, to receive feedback and confirm insights.



1. **Obstacle Exercise:**

Question: What are key challenges you (can) face in adoption of digital twin technologies?

a) Data sharing and integration issues
Insight: Successful adoption of digital twin technologies is heavily reliant on effective data sharing and integration. However, mistrust in external data systems, lack of contextual understanding, and challenges in handling large data volumes hinder the seamless flow of information necessary for optimizing digital twin applications.

b) Organizational resistance to change & leadership buy-in
Insight: Resistance from stakeholders, whether due to fears of transparency, competition, or internal misalignment, poses a significant hurdle to digital twin adoption. Also, frequent leadership changes and short-term focus among executives can derail long-term digital transformation initiatives.

c) Usability and incremental implementation
Insight: Ensuring that digital twin solutions are accessible and usable across various organizational levels is critical. An incremental implementation approach focusing on improving individual processes can mitigate resistance and enhance usability.

d) Need for standardization and regulatory clarity
Insight: The lack of standardization across regions and industries, coupled with regulatory uncertainty, complicates adoption. Clear and consistent standards are essential to streamline implementation and ensure compliance.

e) Process complexity and optimization challenges
Insight: Misunderstandings about the optimization capabilities of digital twins and the complexity of existing processes hinder their adoption. Addressing these misconceptions and demonstrating clear, measurable benefits can encourage wider acceptance.

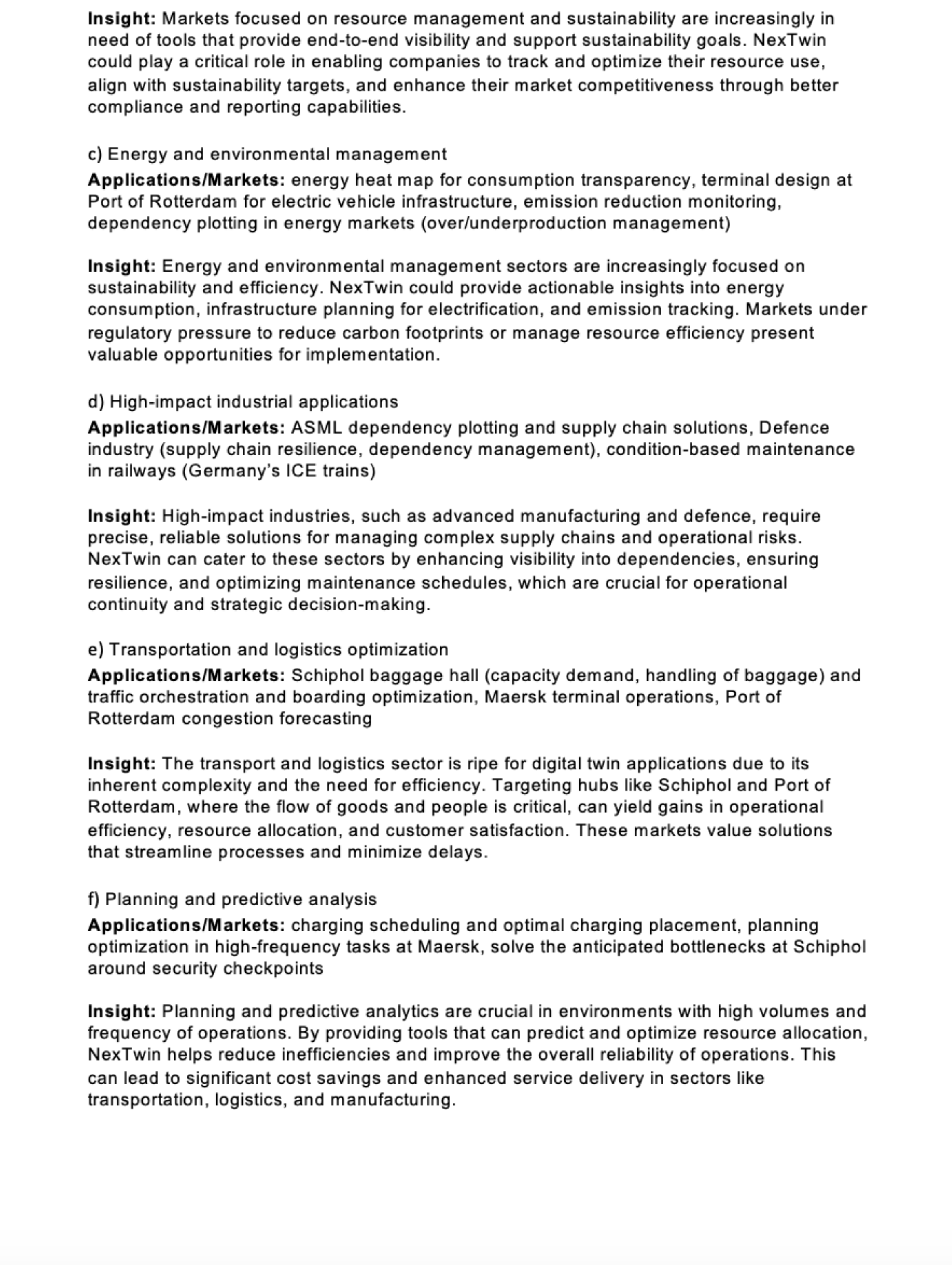
2. **Ideal Market Fit Exercise**

Questions: What would an ideal market look like? Who are the main stakeholders? What urgent problem does NexTwin solve for them?

a) Critical infrastructure and regulation-driven markets
Applications/Markets: CER directive in 2025 (EU regulation for critical infrastructure), dependencies in sectors like water, energy, ports, healthcare regulation and production compliance

Insight: Critical infrastructure and regulation-driven markets are key targets due to their mandated need for compliance and risk management. Digital twins like NexTwin can help organizations meet regulatory requirements, ensure operational transparency, and improve resilience against disruptions. These markets are attractive due to their readiness to invest in compliance-driven innovations.

b) Resource management and sustainability
Applications/Markets: resource-heavy industries (bulk goods, metals, coal), emission tracking across supply chains, centralized port responsibility and sustainability initiatives.



Insight: Markets focused on resource management and sustainability are increasingly in need of tools that provide end-to-end visibility and support sustainability goals. NexTwin could play a critical role in enabling companies to track and optimize their resource use, align with sustainability targets, and enhance their market competitiveness through better compliance and reporting capabilities.

c) Energy and environmental management

Applications/Markets: energy heat map for consumption transparency, terminal design at Port of Rotterdam for electric vehicle infrastructure, emission reduction monitoring, dependency plotting in energy markets (over/underproduction management)

Insight: Energy and environmental management sectors are increasingly focused on sustainability and efficiency. NexTwin could provide actionable insights into energy consumption, infrastructure planning for electrification, and emission tracking. Markets under regulatory pressure to reduce carbon footprints or manage resource efficiency present valuable opportunities for implementation.

d) High-impact industrial applications

Applications/Markets: ASML dependency plotting and supply chain solutions, Defence industry (supply chain resilience, dependency management), condition-based maintenance in railways (Germany's ICE trains)

Insight: High-impact industries, such as advanced manufacturing and defence, require precise, reliable solutions for managing complex supply chains and operational risks. NexTwin can cater to these sectors by enhancing visibility into dependencies, ensuring resilience, and optimizing maintenance schedules, which are crucial for operational continuity and strategic decision-making.

e) Transportation and logistics optimization

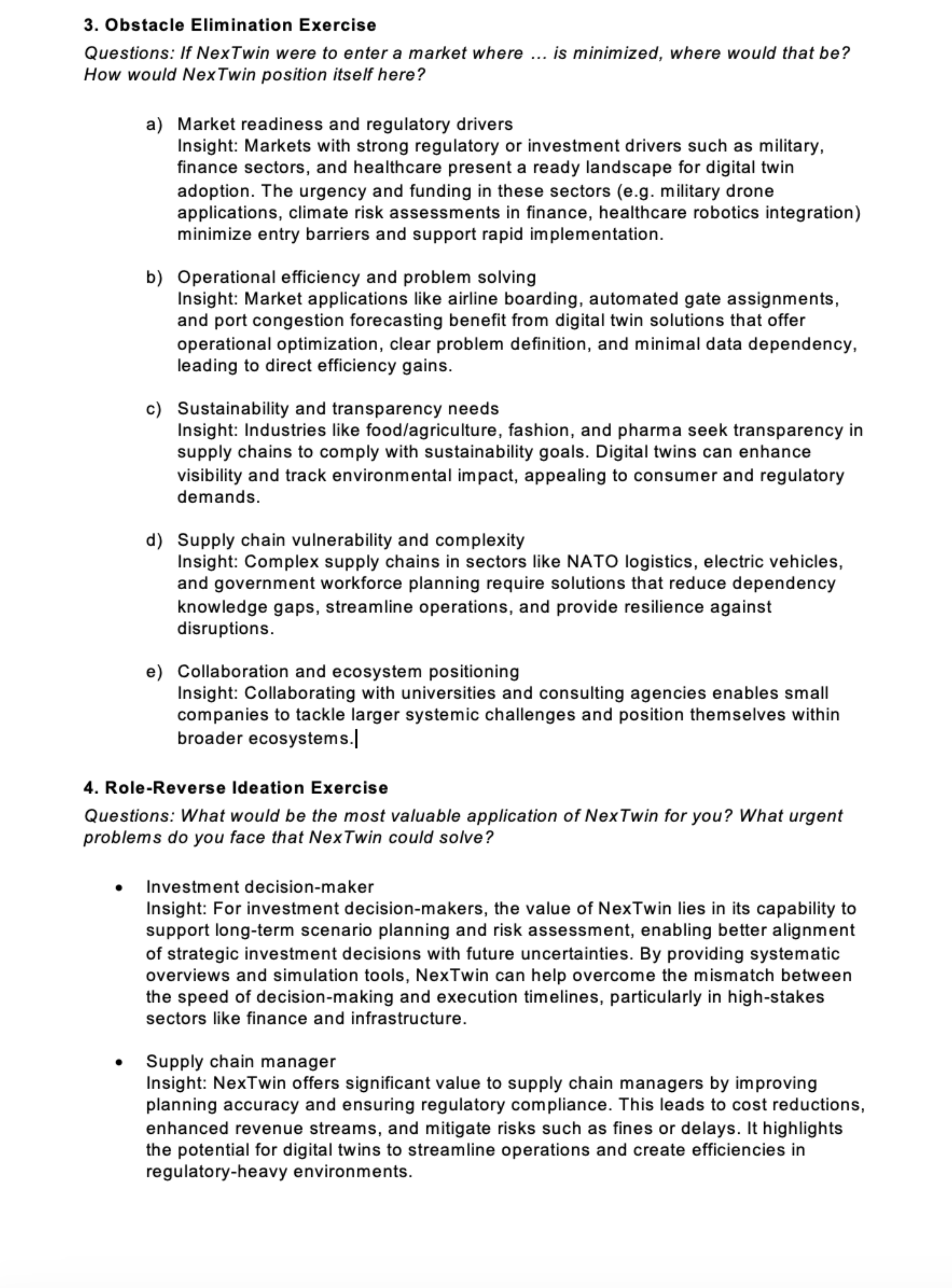
Applications/Markets: Schiphol baggage hall (capacity demand, handling of baggage) and traffic orchestration and boarding optimization, Maersk terminal operations, Port of Rotterdam congestion forecasting

Insight: The transport and logistics sector is ripe for digital twin applications due to its inherent complexity and the need for efficiency. Targeting hubs like Schiphol and Port of Rotterdam, where the flow of goods and people is critical, can yield gains in operational efficiency, resource allocation, and customer satisfaction. These markets value solutions that streamline processes and minimize delays.

f) Planning and predictive analysis

Applications/Markets: charging scheduling and optimal charging placement, planning optimization in high-frequency tasks at Maersk, solve the anticipated bottlenecks at Schiphol around security checkpoints

Insight: Planning and predictive analytics are crucial in environments with high volumes and frequency of operations. By providing tools that can predict and optimize resource allocation, NexTwin helps reduce inefficiencies and improve the overall reliability of operations. This can lead to significant cost savings and enhanced service delivery in sectors like transportation, logistics, and manufacturing.



3. Obstacle Elimination Exercise

Questions: If NexTwin were to enter a market where … is minimized, where would that be? How would NexTwin position itself here?

a) Market readiness and regulatory drivers
Insight: Markets with strong regulatory or investment drivers such as military, finance sectors, and healthcare present a ready landscape for digital twin adoption. The urgency and funding in these sectors (e.g. military drone applications, climate risk assessments in finance, healthcare robotics integration) minimize entry barriers and support rapid implementation.

b) Operational efficiency and problem solving
Insight: Market applications like airline boarding, automated gate assignments, and port congestion forecasting benefit from digital twin solutions that offer operational optimization, clear problem definition, and minimal data dependency, leading to direct efficiency gains.

c) Sustainability and transparency needs
Insight: Industries like food/agriculture, fashion, and pharma seek transparency in supply chains to comply with sustainability goals. Digital twins can enhance visibility and track environmental impact, appealing to consumer and regulatory demands.

d) Supply chain vulnerability and complexity
Insight: Complex supply chains in sectors like NATO logistics, electric vehicles, and government workforce planning require solutions that reduce dependency knowledge gaps, streamline operations, and provide resilience against disruptions.

e) Collaboration and ecosystem positioning
Insight: Collaborating with universities and consulting agencies enables small companies to tackle larger systemic challenges and position themselves within broader ecosystems.

4. Role-Reverse Ideation Exercise

Questions: What would be the most valuable application of NexTwin for you? What urgent problems do you face that NexTwin could solve?

- Investment decision-maker
  Insight: For investment decision-makers, the value of NexTwin lies in its capability to support long-term scenario planning and risk assessment, enabling better alignment of strategic investment decisions with future uncertainties. By providing systematic overviews and simulation tools, NexTwin can help overcome the mismatch between the speed of decision-making and execution timelines, particularly in high-stakes sectors like finance and infrastructure.

- Supply chain manager
  Insight: NexTwin offers significant value to supply chain managers by improving planning accuracy and ensuring regulatory compliance. This leads to cost reductions, enhanced revenue streams, and mitigate risks such as fines or delays. It highlights the potential for digital twins to streamline operations and create efficiencies in regulatory-heavy environments.

- Sustainability manager
  Insight: Sustainability managers can leverage NexTwin for cradle-to-grave visibility, which aids in pinpointing areas of high environmental impact. This utility extends across multiple stakeholders, enabling better decision-making in selecting sustainable products and meeting regulatory or consumer demands.

- Data distinction in applications (comment)
  Insight: The distinction between real-time data and data for scenario planning is crucial. NexTwin's ability to use the right data for the right purpose, which is real-time for immediate decision and historical or predictive data for long-term forecasting, ensures that the tool remains relevant and effective across various applications.

5. Narrowing Down Exercise: best options

1. (3 votes) Schiphol baggage belt & gate assignment optimization

2. (2 votes) Dutch Ministry of Defence supply chain visibility
3. (2 votes) Port of Rotterdam congestion forecaster
4. (2 votes) Schiphol staff & task planning optimization (demand/capacity)

5. (1 vote) ASML supply chain visibility
6. (1 vote) finance sector weather & climate impact
7. (1 vote) health care sector supply chain visibility
8. (1 vote) car battery supply chain twin
9. (1 vote) Schiphol airplane boarding sequence
10. (1 vote) Dutch economy dependencies (water/energy/etc.) (visibility of vulnerabilities)

F. Extended PSF Process Visuals

This appendix presents extended visuals of the Problem-Solution Fit (PSF) process. It includes a one-page, 30-second-read guide designed for quick reference by ventures facing the “solution looking for a problem“ dilemma, alongside a more detailed three-page, five-minute-read guide. These materials offer practical and visually engaging overviews of the PSF process, highlighting its key steps and applications.

F1. One-Pager

F2. Three-Pager

F1. One-Pager

A GUIDE FOR SOLUTIONS LOOKING FOR A PROBLEM

Many deep-tech solutions start with innovation but lack a clear problem to solve. The **Reverse Hackathon** offers a structured co-creation workshop designed to uncover and validate real problems through stakeholder collaboration.

How It Works

The Reverse Hackathon shifts focus from solutions to **problems first** in three phases:

1. **Exploration**: Identify assumptions, map stakeholders, and uncover potential problems through research and industry conversations.

2. **Reverse Hackathon** (Core Activity): A structured 3-4 hour workshop where stakeholders:
   - Brainstorm problems individually and as a group
   - Define the ideal market where the solution thrives
   - Eliminate obstacles to identify industries with low barriers
   - Test ideas through role-reversal ideation (e.g. supply chain managers, sustainability leads, investment-decision makers)
   - Prioritise problems based on impact and feasibility

3. **Decision**: Assess validated problems to decide whether to **pursue**, **pivot**, or **pause** development.

By bringing real-world industry insights into the process, the Reverse Hackathon shifts the focus from abstract technology to actionable problem definitions, forming the foundation for future commercialisation.

Why use it?

- **Uncover Real Problems:** Move beyond assumptions to stakeholder-backed insights
- **Accelerate Alignment:** Gain buy-in through co-creation and prioritisation
- **Save Time:** Achieve in hours what might take weeks of fragmented research

Adapted from the Reverse Hackathon method by Romme (2023).

F2. Three-Pager

A GUIDE FOR SOLUTIONS LOOKING FOR A PROBLEM

A structured approach for early-stage technologies
to identify Problem-Solution Fit (PSF)

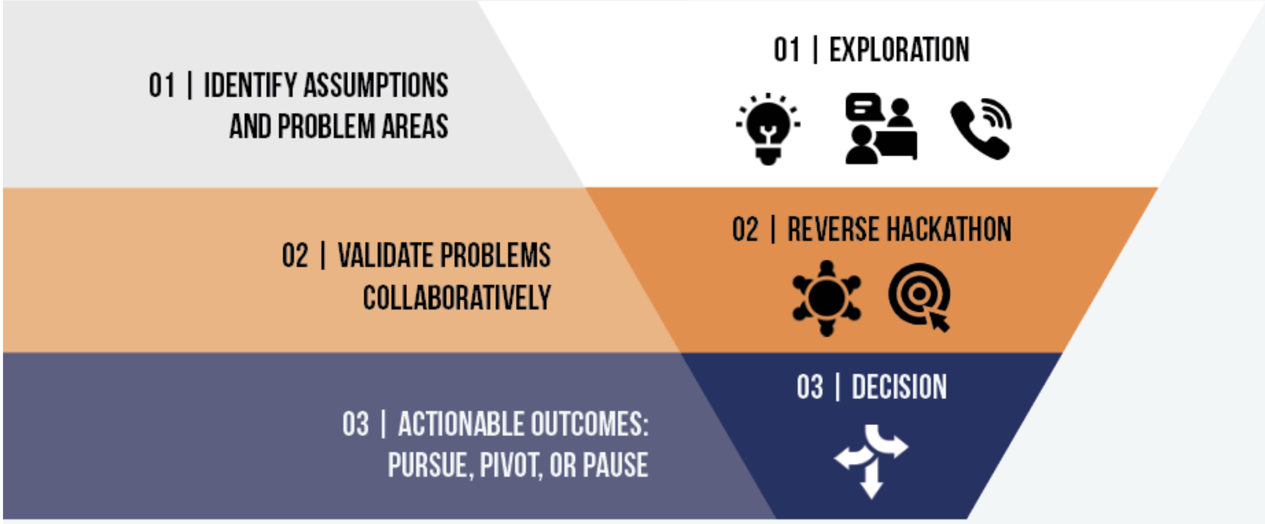
Why use a Reverse Hackathon?

- **Shift to "Problem-First" Thinking**: Focus on defining and validating problems before pursuing solutions
- **Accelerate Insights**: Achieve in hours what could take weeks with interviews and fragmented research
- **Real Case: Docklab and NexTwin**: *"Docklab used a Reverse Hackathon to address the ambiguity of its digital twin technology. By inviting diverse industry players, they identified real-world problems, including a use case that led to follow-up discussions with a potential client. This transformed NexTwin from a solution in search of a problem to a tangible market opportunity."*

The PSF Framework

The Reverse Hackathon is the core activity of a 3-phase process:

1. **Exploration**: Identify assumptions, map stakeholders, and uncover initial problem areas
2. **Reverse Hackathon** (Validation phase): Co-create, refine, and prioritise problems in a structured 3-4 hour session
3. **Decision**: Validate problems and determine whether to pursue, pivot, or pause development



01 | IDENTIFY ASSUMPTIONS AND PROBLEM AREAS

01 | EXPLORATION

02 | VALIDATE PROBLEMS COLLABORATIVELY

02 | REVERSE HACKATHON

03 | ACTIONABLE OUTCOMES: PURSUE, PIVOT, OR PAUSE

03 | DECISION

Adapted from the Reverse Hackathon method by Romme (2023).

How to Run a Reverse Hackathon

1. PREPARATION

Goal: Set the foundation with the right people and materials.

Who to Invite (3-12 Participants):
- **Potential Clients**: Supply chain managers, sustainability leads, operations managers, digital transformation leads
- **Industry Experts**: Technical experts, consultants, and researchers
- **Internal champions**: Product managers, developers, and business strategists

Tips for Invitations:
- Frame invites as an opportunity to influence innovation
- Highlight their role as "industry experts" shaping real-world solutions
- Use LinkedIn or professional networks to reach out

Materials: Whiteboards, sticky notes, prioritisation templates, markers, and refreshments

2. EXECUTION (3-4 HOURS)

Key Activities:

- **Introduction:** Set goals and introduce the solution
- **Problem Brainstorm**: Stakeholders identify problems individually, then group into themes
- **Ideal Market Exercise**: Describe what the "ideal market" would look like for the solution
- **Obstacle Elimination**: Identify markets where key barriers are lower
- **Role-Reversal Ideation**: Groups discuss problems from key stakeholder roles
- **Prioritisation**: Vote on the most impactful and feasible problems to focus on

3. FOLLOW-UP (1 WEEK AFTER)

- Report Insights: Summarise validated problem statements and key takeaways
- Drive Action: Plan next steps (follow-up calls, further research, or pilot tests)

Tip: Always document insights and decisions to maintain momentum.

Adapted from the Reverse Hackathon method by Romme (2023).

Case Study: From Solutions to Opportunities

Challenge: A deep-tech venture developing a highly versatile technology struggled to identify clear problem areas or markets for its capabiltiies. Early efforts focused on broad outreach and generalised value propositions, which failed to generate stakeholder interest or pilot opportunities.

Solution: The team organised a Reverse Hackathon to engage key industry stakeholders, co-create problem definitions, and refine potential use cases. By involving decision-makers, technical experts, and potential end users from target sectors, the session uncovered high priority challenges where the technology could deliver measurable value.

Results:

- Identified actionable use cases in sectors with strong regulatory and operational drivers
- Shifted the technology's narrative from a general-purpose tool to a **sector-specific enabler,** clarifying its unique value proposition
- Pinned down phased pilot opportunities, reducing perceived risks for stakeholders and paving the way for collaboration

Practical Tips for Facilitators

1. **Frame the session with clear goals:** Start with 3-5 problem prompts aligned with your technology's strengths. These prompts should balance focus with openness to diverse ideas (e.g. "What operational challenges could benefit from predictive data systems?")
2. **Diversify your participants**: Include potential users, technical experts, and decision-makers to ensure a range of perspectives. Cross-industry insights can reveal unexpected opportunities. Make sure to not include more than 3 internal team members in bigger groups.
3. **End with prioritised outcomes**: Conclude the session with a prioritisation activity to focus on the most actionable and feasible problem areas. Use voting or ranking tools to guide the group towards agreement.

Adapted from the Reverse Hackathon method by Romme (2023).