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Mitigating Vendor Lock-in in the ERTMS Program: Exploring Strategies applied in the Railway Infrastructure Domain

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Colophon

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Preface

This thesis marks the completion of my master's degree in construction engineering & management at the University of Twente. The research was conducted between September 2023 and March 2024 during my internship at the head office of ProRail in Utrecht.

I want to express my sincere gratitude to my supervisor at ProRail, Matthijs Kuhlmann, for his invaluable guidance and support throughout my internship, extending even beyond the formal duration of my contract.

Furthermore, I would like to express my appreciation to my academic supervisors at the University of Twente, Leentje Volker and Wilco Tijhuis. Their insightful feedback sessions gave me valuable perspectives that significantly influenced my research.

I am grateful to everyone who contributed to this research. During interviews and the expert panel discussion, individuals from ProRail, Thales, Programma Directie ERTMS, and even RET were consistently helpful and willing to share their expertise. A special thanks to Gijsbert van de Waerdt, PhD candidate at the University of Twente, for participating in the expert panel and providing valuable insights.

I extend my thanks to my colleagues at ProRail, particularly Errol Haakmat and Jorick Straatman, for the moments we shared and their support. I am also grateful to my fellow students, friends, and family for their contributions and support throughout this research.

This thesis represents a significant milestone in my career, and I am excited about what the future has to bring.

I hope this thesis contributes to a deeper understanding of vendor lock-in risks in the field of Construction Engineering and Management.

Enjoy reading this thesis.

Sander Krakers

Nijmegen, 27 May, 2024

Executive Summary

De Nederlandse spoorwegsector staat voor een cruciale transitie. De toenemende mobiliteitsbehoefte en de druk van klimaatverandering vereisen een robuuster en beter geïntegreerd spoorwegsysteem dat meer veiligheid en betrouwbaarheid biedt. Echter, de huidige infrastructuur kent beperkingen, waardoor modernisering onvermijdelijk is. Digitalisering speelt hierbij een sleutelrol, maar verhoogt ook de complexiteit en introduceert nieuwe uitdagingen zoals vendor lock-in. Dit fenomeen, waarbij een opdrachtgever ongewild afhankelijk wordt van een leverancier, kan leiden tot opportunistisch gedrag en onnodig hoge kosten. Ondanks de significante impact, blijft vendor lock-in een onderbelicht probleem binnen de infrastructuursector. Vendor lock-in wordt veroorzaakt door de complexiteit van infrastructurele programma's en de noodzaak van raamovereenkomsten. Deze overeenkomsten, die bedoeld zijn om stabiliteit en continuïteit te bieden, kunnen juist leiden tot hoge toetredingsdrempels voor nieuwe leveranciers en aanzienlijke overstapkosten voor de opdrachtgever. Dit vermindert de flexibiliteit en bevordert afhankelijkheid. Leveranciers kunnen dit uitbuiten, wat resulteert in servicedegradatie en kostenstijgingen.

Om de nadelige effecten van leveranciersafhankelijkheid te beperken, zijn in deze studie diverse mitigatie strategieën onderzocht. Deze strategieën kunnen worden onderverdeeld in contractuele en relationele strategieën. Contractuele strategieën richten zich op mechanismen zoals wederzijdse afhankelijkheid, dual sourcing en flexibele contracten. Relationele strategieën richten zich op het ontwikkelen van dynamische capaciteiten en alliantiecapaciteiten, waardoor samenwerking en aanpassingsvermogen worden bevorderd.

Een casestudie binnen de spoorwegsector onderzoekt hoe vendor lock-in situaties kunnen worden beperkt binnen raamcontracten voor infrastructuurprogramma's. De focus ligt op het Central Safety System (CSS) contract tussen ProRail en Thales, onderdeel van het European Railway Traffic Management System (ERTMS). Deze studie toont aan dat ProRail proactieve maatregelen heeft genomen, zoals het investeren in interne kennisontwikkeling en het opbouwen van een alliantie met Thales. Toch brengt de selectie van één leverancier risico's met zich mee, die nog onvoldoende bekend zijn binnen de sector.

De bevindingen van deze studie benadrukken de noodzaak van bewustwording en proactief risicomanagement. Vendor lock-in kan effectief worden beheerd door strategische maatregelen gedurende de gehele contractperiode. ProRail heeft laten zien dat een combinatie van contractuele en Relationele strategieën essentieel is. Investeren in interne kennis en het bevorderen van allianties zijn cruciaal voor het behouden van flexibiliteit en beheersbaarheid van programma's.

De resultaten van dit onderzoek laten zien dat vendor lock-in binnen complexe infrastructuurprogramma's onvermijdelijk is, maar de negatieve impact kan worden geminimaliseerd door gerichte maatregelen. ProRails aanpak, hoewel effectief, onderstreept de noodzaak van voortdurende aanpassing en strategisch vooruitdenken.

Het is essentieel dat er verdere studies worden uitgevoerd om een grondiger inzicht te verkrijgen in de evoluerende uitdagingen en effectieve strategieën voor het verzachten van risico's binnen de infrastructuur, vooral in de latere fasen van contracten wanneer deze minder aantrekkelijk kunnen worden voor leveranciers. Door een gezamenlijk bewustzijn en samenwerking te bevorderen, kunnen de voordelen van langdurige samenwerkingsverbanden

optimaal worden benut, terwijl de negatieve effecten van vendor lock-in worden geminimaliseerd. Dit is cruciaal voor het ontwikkelen van een duurzame en veerkrachtige infrastructuur die bestand is tegen de uitdagingen van een snel veranderende wereld.

Abstract

In an era where digital transformation is reshaping the infrastructure sector, the challenges posed by vendor lock-in are becoming increasingly critical. This study examines vendor lock-in within infrastructure programs, emphasising the impact of digitalisation, which introduces innovation and complexity, alongside risks of opportunistic behaviour and rising costs. Vendor lock-in arises from long-term client-supplier relationships formed through framework agreements, leading to dependencies that make switching suppliers prohibitively expensive and complex. This dependency can stifle competition, hinder innovation, and drive up costs as suppliers exploit their entrenched positions. Despite the high stakes in the infrastructure sector, vendor lock-in remains underexplored, particularly given the significant capital investments and public service obligations involved.

To address these challenges, this research draws on insights from outsourcing theories, constructing a framework based on transaction cost economics and agency theory. This framework delineates the causes, risks, and consequences of vendor lock-in, highlighting how digitalization and framework agreements contribute to high entry barriers and switching costs, thus reinforcing lock-in. Market dynamics, including limited supplier pools, asset specificity, and potential for opportunistic behaviour, further exacerbate these risks, leading to service degradation and cost escalation.

The practical application of this model is demonstrated through a case study of ProRail's Central Safety System (CSS) contract with Thales within the European Rail Traffic Management System (ERTMS) program. The case study illustrates how vendor lock-in manifests and can be mitigated in large infrastructure programs. ProRail employed a combination of contractual and relational strategies, such as mutual hostaging, flexible contracting, and fostering dynamic capabilities, to address lock-in risks.

Findings reveal that despite ProRail's proactive measures, challenges persist in maintaining contract attractiveness and managing the complexities of large-scale programs. This underscores the necessity for continuous adaptation and strategic foresight in managing vendor lock-in. The study highlights the importance of industry-wide awareness and proactive risk management to ensure the success and efficiency of infrastructure programs. Further research is recommended to explore vendor lock-in across various complex contracts, particularly in later stages, to develop deeper insights and effective mitigation strategies. This research provides valuable guidance for practitioners and policymakers, offering strategic recommendations to navigate the challenges of vendor lock-in and promote competitive, innovative, and cost-effective infrastructure program outcomes.

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1. Introduction

In the introductory chapter, the relevance and applicability of the research will be discussed. This will be followed by an identification of the research gap. The chapter will also define the parameters of the study, pose the research questions, and provide a guide to navigate the subsequent sections of this thesis.

1.1. Rail Transport in the Netherlands

The Dutch railway system recognized as the busiest railway network in the European Union (Dielesen, 2019), serves as a cornerstone of the Netherlands' commitment to efficient and sustainable transportation. It facilitates the daily movement of over 1.3 million passengers and plays a pivotal role in freight transport. This network, vital for the nation's economic prosperity and social well-being (Rinaldi et al., 2001), stands as the busiest in the European Union. Its significant activity not only supports economic activities and reduces road traffic congestion but also enhances environmental sustainability by providing a greener alternative to road transport. Such attributes underscore the critical role of the Dutch railways in fostering efficient movement of people and goods across the country, reflecting their essential contribution to the nation's infrastructure.

However, the system faces significant pressures that threaten its ability to meet future demands. Increasing prosperity and growing mobility demands are expected to escalate substantially in the coming decades. These trends challenge the resilience of the existing infrastructure. The obsolescence of some parts of the railway infrastructure further exacerbates these issues (Vosman, 2020), necessitating comprehensive modernization and expansion efforts.

The Dutch railway sector is at a junction point. On the one hand, it faces a projected surge in demand, necessitating a more robust and interconnected system with enhanced safety and reliability (Lo & Meijer, 2020). On the other hand, the current infrastructure, constrained by spatial and physical limitations, cannot easily expand its track network. This bottleneck presents a significant barrier to accommodating the anticipated increase in passenger and freight volumes (Li et al., 2020).

Moreover, the sector must navigate these challenges while balancing the need for technological innovation and sustainability. Integrating advanced technologies and adopting sustainable practices is crucial for enhancing the efficiency and resilience of the railway system. However, these efforts must be carefully managed to avoid disruptions and ensure that the benefits are realized across the entire network.

1.2. ERTMS

The current rail safety system in the Netherlands, which dates back to the 1960s, is increasingly inadequate in meeting the rising demands of modern carriers and passengers. The outdated nature of this system poses significant challenges, including safety risks and inefficiencies that hinder the overall performance of the railway network. As the volume of rail traffic continues to grow, the need for modernization becomes ever more pressing.

To address these challenges, the Netherlands is undertaking efforts to integrate the European Rail Traffic Management System (ERTMS), a cutting-edge technology designed to enhance safety, interoperability, and efficiency across the railway system (ERTMS, 2024). ERTMS represents a significant step forward, providing a unified and standardized framework that can accommodate higher traffic volumes while improving safety and reducing delays.

ProRail, the organization responsible for railway infrastructure in the Netherlands, plays a pivotal role as the client in this modernization initiative. Implementing ERTMS involves coordination among various stakeholders, including infrastructure suppliers, operators, and regulatory bodies. Each of these parties has distinct responsibilities and priorities, which can sometimes conflict and create challenges in achieving a seamless integration (Aaltonen et al., 2010). Successful implementation requires breaking down the broader system integration challenges into manageable inter-organizational projects, ensuring that each component is effectively aligned with the overarching goals.

The failed implementation of the Dutch high-speed train FYRA serves as a cautionary tale, highlighting the risks and difficulties associated with large-scale railway projects (Jakubeit, 2023). Lessons learned from this experience underscore the importance of thorough planning, stakeholder collaboration, and risk mitigation in future projects. By applying these lessons, the Netherlands aims to navigate the complex socio-technical landscape of railway modernization and achieve a safer, more efficient rail network.

The European Rail Traffic Management System (ERTMS) aims to address the challenge of modernizing the Dutch railway system by transitioning from an analogue, signal-based system to a modern, digitalized ICT system. This modernization effort will enable faster, safer, and closer train operations, thereby significantly increasing network capacity (ProRail, 2023). Consequently, more trains can be utilized to meet contemporary demands, facilitating quicker and more sustainable trans-European rail travel. ERTMS enhances interoperability between different national railway systems, making international travel more seamless and efficient.

This program, launched by the Ministry of Infrastructure, serves as an example of a far-reaching initiative. Spanning decades, it demands deep inter-organizational collaborations and extensive stakeholder engagement, thereby requiring specialized roles and dedicated responsibilities. (Hällström, 2023). Collaborative practices are essential to navigate the inter-organizational dynamics and numerous interfaces (Biesenthal et al., 2018).

The complexities of modernizing the Dutch railway system necessitate a shift from traditional project-based approaches to strategic program management. In this approach, public and private entities engage in a series of interconnected projects over an extended timeframe (Frederiksen et al., 2021). This programmatic approach ensures a holistic perspective and continuous alignment with long-term objectives, allowing for adaptive management as circumstances evolve.

Each stage necessitates different actor configurations with distinct temporal boundaries (Brookes et al., 2017). Precedence relationships are often established, requiring the completion of specific program elements before initiating new projects. Over the life cycle, each phase progressively contributes to value creation, culminating in the program's complete execution and the realisation of benefits during operations (Söderlund et al., 2017). Similar to the role of a meta-systems integrator during the London 2012 Olympics (Davies et al., 2009), an umbrella program can be established to oversee the entire life cycle of the Dutch railway modernisation effort. This overarching program structure provides a framework for overcoming fragmentation and fostering collaboration among diverse stakeholders (Denicol et al., 2023).

The extended duration of programs like ERTMS requires a stronger focus on relational and contractual governance mechanisms, which significantly impact program outcomes compared

to individual projects. Program contracts must be flexible enough to adapt to unforeseen circumstances during execution. Framework agreements, a common type of program contract, structure programs into phases with built-in learning loops. Each phase serves as a reference point for the next, fostering an iterative learning process (Pellegrinelli et al., 2007). The unique nature of these agreements necessitates a distinct governance approach that departs from traditional project governance practices in infrastructure delivery.

To facilitate the ERTMS program. ProRail established a framework agreement extending beyond traditional engineering. The agreement encompasses the development, ICT engineering, delivery, and long-term maintenance of the ERTMS Central Safety System. Recognising the inherent complexities and potential for unforeseen changes during implementation, ProRail prioritised flexibility within the contract structure. This flexibility allows the program to adapt to system requirements and market developments.

To guarantee operational continuity and adaptability, the ERTMS program in the Netherlands prioritizes a measured rollout strategy. Instead of introducing changes all at once to the entire network, this method introduces them gradually over specific track segments. This phased approach reduces the risk of widespread disruption and allows for iterative testing and refinement. Considering the size and unpredictability of ERTMS, ProRail has implemented a "transition phase" that includes the yellow dashed segments in Figure 1.

Figure 1: ERTMS Implementation Segments in the Netherlands (ERTMS, 2024)

In the railway sector, and more broadly in the infrastructure sector, organizations are structured around project-oriented models that focus on specific, independent undertakings (Vosman, 2020). These organisations collaborate with diverse actors in temporary coalitions to deliver unique products. This project-centric approach fosters fragmentation, with each project alone without connection to past or future efforts (Dubois & Gadde, 2002).

Program management, while offering several advantages, faces considerable challenges in its application within the project-based nature of the infrastructure industry (Martinsuo & Hoverfält, 2018). Program contract agreements are characterized by elevated levels of customization, rigorous risk management, and enduring commitments, binding the program owner to the supplier (Pitsis et al., 2018). With the programmatic working model still being relatively new in the infrastructure sector, there is a limited understanding of the risks tied to these new types of contractual arrangements (Denicol et al., 2023). One of those risks is 'vendor lock-in,' where dependency on a specific supplier can lead to reduced flexibility and increased costs over time.

1.3. Vendor Lock-In

Vendor lock-in refers to a scenario where a client becomes overly dependent on a single supplier, making it difficult and costly to switch suppliers or alter agreements. This phenomenon is particularly relevant in the context of framework agreements, which often foster close and intimate relationships between the client and the supplier. These agreements enable the client to place significant trust in the supplier's expertise and follow their technical direction, often leading to innovative initiatives driven by the supplier's insights. However, this trust-based relationship can have a notable drawback: the client's influence on decision-making is significantly diminished, primarily hinging on trust (Etro, 2004).

As the client increasingly relies on the supplier, it becomes locked into a constrained partnership. The complexity involved in large-scale infrastructure programs such as the ERTMS programs means there is limited flexibility to change suppliers without facing high costs (Opara-Martins et al., 2016). The supplier, aware of the program client's limited alternatives, may become complacent, hindering collaboration and stifling innovation (Sjoerdstra, 2016). This situation, commonly referred to as vendor lock-in, can be defined as a scenario where a client is unable to exit a relationship without facing significant losses or giving up some or all of its assets to the supplier (Aubert et al., 1998).

By examining the strategies employed by ProRail within the ERTMS program, this study seeks to understand how vendor lock-in can be managed and mitigated in large-scale infrastructure programs. It aims to provide insights into the dynamics of vendor lock-in and propose effective strategies to maintain flexibility and foster innovation, even within the confines of long-term framework agreements.

1.4. Contribution to Research & Society

The infrastructure sector exhibits a noticeable deficiency in established knowledge regarding the specific challenges and management practices associated with vendor lock-in within framework agreements. While sectors with extensive outsourcing experience, such as process and IT, are well-versed in managing such situations, the infrastructure sector has not fully explored these dynamics. Consequently, this study seeks to explore how these established sectors tackle vendor lock-in and evaluate the applicability of their strategies to the railway sector. Existing research provides limited insight into the particular manifestations, evolution, and impacts of vendor lock-in within the infrastructure domain, a limitation that constrains a comprehensive understanding of its broader implications.

While vendor lock-in has been thoroughly investigated in sectors like IT, the findings have not been fully contextualized to meet the distinct needs of the infrastructure sector. This presents a critical research opportunity to determine how mitigation strategies employed in other sectors

can be effectively adapted and implemented within the infrastructure domain. By addressing this gap, the study aims to contribute to a more nuanced understanding of vendor lock-in in infrastructure programs and to develop strategies that can be broadly applied across different sectors.

Vendor lock-in presents a substantial threat to the successful execution of crucial infrastructure programs, marking it as a significant societal concern. Organizations such as ProRail, tasked with overseeing large-scale infrastructure programs, are potentially more vulnerable and less adaptable due to inadequate strategies for mitigating vendor lock-in. This vulnerability could compromise the accomplishment of initiatives that have broad societal advantages, such as the development of transportation systems, raising safety standards, and fostering economic growth. Thus, creating strong plans to control and lessen vendor lock-in is crucial to the longevity and accomplishment of large-scale infrastructure programs.

1.5. Research Framework

As the infrastructure sector transitions from individual programs to more comprehensive, program-based approaches, the use of comprehensive framework agreements for large-scale initiatives presents a unique challenge in mitigating vendor lock-in situations. Vendor lock-in, characterized by a heavy reliance on a single supplier that restricts adaptability and innovation, emerges as a significant risk within the context of framework agreements.

The primary objective of this study is to develop a comprehensive strategy for mitigating vendor lock-in within infrastructure programs executed through framework agreements. This strategy aims to be informed by a thorough exploration of the specific challenges and characteristics associated with vendor lock-in situations within this context. By doing so, it seeks to provide actionable insights and practical solutions that can be implemented by organizations involved in large-scale infrastructure programs.

1.5.1. Research Questions

To investigate this, the following research question is addressed:

"How to mitigate vendor lock-in situations within infrastructure programs covered by framework agreements?"

To achieve this, the following sub-research questions are answered:

- What are the characteristics and challenges of vendor lock-in situations within large infrastructure programs covered by framework agreements?

- What lessons can be drawn from the IT and other industries' experiences with vendor lock-in prevention, and can these lessons be adapted for the infrastructure sector?

- How can ProRail enhance its strategies within the CSS contract as part of the ERTMS program to mitigate the risks associated with vendor lock-in situations?

1.5.2. Research Boundaries

The research is limited to the setting of infrastructure programs in which framework agreements are used to foster supplier relationships. Although vendor lock-in can occur in various business contexts, this study highlights the specifics of the phenomenon within the Dutch Railway sector. The study uses a single, in-depth case study to provide detailed insights

into vendor lock-in while recognizing that it might not accurately reflect the diversity of infrastructure programs worldwide. A cautious approach is necessary when applying the findings to other contexts, as challenges and mitigation strategies may differ significantly across national borders.

This research concentrates on the overall structure and management of the program, particularly the client-supplier relationship and the agreements they have in place. Although the study recognizes the value of other aspects of program management, it does not attempt to address every aspect of those fields. Instead, it highlights the pertinent details that can assist in comprehending how to prevent vendor lock-in in infrastructure programs.

1.6. Reading Guide

In the forthcoming chapter, the case study background is elaborated upon, with an in-depth explanation of the decisions made and their impact on vendor lock-in. Following the theoretical groundwork established in Chapter 3, which draws insights from various sectors, this study develops a conceptual model and vendor lock-in framework tailored for the railway industry. The applicability of this framework is examined through a single case study approach, focusing on the framework agreement between Thales and ProRail for the Central Safety System (CSS) of the ERTMS program in the Netherlands.

Chapter 3 outlines the methodology employed in analysing the case study. It describes the research design and the data collection techniques used, including document analysis, interviews, and expert panel validation. Chapter 4 presents the findings, providing insights into the mitigation techniques for vendor lock-in observed in the case study, and highlighting the discrepancies between these practical measures and the theoretical models.

Chapter 5 evaluates the differences between the empirical results and the theoretical framework, discusses the limitations of the study, and suggests directions for future research in the infrastructure industry. Finally, Chapter 6 concludes the study by addressing the research questions and offering recommendations for ProRail and the railway industry.

2. Case Study: Central Safety Contract ERTMS

This research employs a single case study approach (Gustafsson, 2017) to explore vendor lock-in within programmatic collaborations for large-scale infrastructure programs. The focus of the case study is the Central Safety System (CSS) contract, which is a crucial component in the digitalisation of the Dutch Railway network managed by ProRail, the public owner responsible for the rail infrastructure in the Netherlands.

2.1. Case Study Background & Objectives

The European Rail Traffic Management System (ERTMS) program represents a significant initiative aimed at transitioning the Dutch railway system from an outdated, analogue signal-based system to a state-of-the-art, digitalised ICT system. This transformation is not only essential to accommodate the increasing demands on the railway network but also to ensure quicker, safer, and more sustainable trans-European rail travel, aligning with broader European transportation goals (ProRail, 2023). To facilitate this complex and ambitious program, ProRail established a comprehensive framework agreement. This agreement encompasses various aspects, including the development, ICT engineering, delivery, and long-term maintenance of the ERTMS Central Safety System. A key priority within the contract structure is flexibility, allowing the system to adapt to evolving requirements and market developments.

One of the primary challenges faced in this program is the limited pool of qualified suppliers capable of delivering such a complex system, which presents a significant risk of vendor lock-in. Vendor lock-in occurs when a customer becomes overly dependent on a single supplier, making it difficult to switch to another vendor without substantial costs or inconvenience. To mitigate this risk, ProRail recognised the importance of collaboration as a critical strategy. Their procurement methodology was designed to incorporate criteria that specifically evaluated potential bidders on their collaborative approach. Moreover, the contract includes incentives for knowledge sharing between stakeholders through "open-engineering" practices, serving as a proactive measure against vendor lock-in (Opara-Martins et al., 2016). Collaboration is essential throughout all phases of the program—development, roll-out, and maintenance—to ensure its success.

During the tendering process, extensive discussions with potential bidders further underscored the value of collaboration. By May 2022, Thales, an electronics company with extensive expertise in transportation, defence, and information technology (Thales, 2023), emerged as the winning bidder and subsequently signed the framework agreement with ProRail. Thales was awarded a contract with a maximum duration of 37 years, structured to include twelve years dedicated to development and delivery. After eight years, a decision will be made regarding the renewal of the contract, allowing for adjustments based on performance and changing needs.

To ensure operational continuity and adaptability, the ERTMS program in the Netherlands prioritises a measured rollout strategy. Rather than implementing changes across the entire network simultaneously, this method involves introducing modifications gradually over specific track segments. This approach acknowledges the size and unpredictability of the ERTMS, allowing for more controlled and manageable implementation. As part of this strategy, ProRail has implemented a "transition phase" that includes three railway segments. This staged deployment approach, enabled by the contractual framework, permits modifications during the ongoing development phase. In a rapidly changing technological

environment, this strategic approach fosters an atmosphere conducive to innovation and adaptation.

2.2. Addressing Vendor Lock-In Risks

Given the complexity and limited supplier market for the Central Safety System (CSS), vendor lock-in emerges as a significant concern for ProRail. The CSS's highly specialized nature means only three system suppliers possess the capability to deploy it in the Netherlands. This scarcity necessitates a strategic plan from ProRail to minimize the risk of opportunistic behaviour by suppliers, ensuring the program's smooth progression and sustainability.

The extensive scope of the CSS program, encompassing multiple facets of railway safety and operations, makes it an attractive venture for suppliers. It balances the needs of the market with the suppliers' capabilities, driving innovation and competitiveness. Furthermore, the adoption of ERTMS as a standard across Europe potentially broadens the pool of available suppliers. However, the presence of disparate national train security systems among EU member states poses substantial challenges to the adoption of a unified standard, thereby increasing the likelihood of vendor lock-in scenarios.

To better understand and mitigate these risks, ProRail conducted a thorough examination of various strategies employed by other European countries in their ERTMS implementations. This comparative analysis aimed to glean insights from different contractual and relational approaches to managing supplier relationships and mitigating the risk of vendor lock-in. Table 1 below presents an overview of the different agreement models used across Europe, highlighting the diversity in managing such large-scale infrastructure programs.

Table 1: Agreement Models used for implementing ERTMS across Europe

Country	**Agreement Model**
Italy	Framework agreement – two suppliers
Denmark	Equal plots – two parties
Switzerland	Framework agreement – two suppliers
Norway	Framework agreement – one supplier
Spain	Per corridor
Belgium	All-in-one
France	Per corridor
Sweden	Framework agreement – two suppliers
United Kingdom	Framework agreement – four suppliers
Germany	Per corridor / Framework agreement

By studying these various models, ProRail can derive lessons on structuring its contracts to balance the advantages of collaboration while avoiding excessive dependency on a single supplier. This detailed analysis helps ProRail tailor its strategy, leveraging best practices from across Europe and addressing the unique challenges posed by the Dutch railway system.

ProRail's historical programs, such as the ‘Havenspoorlijn train security contract’ and the ‘HSL-Zuid,’ highlight financial risks associated with single-supplier dependencies. Managing multiple suppliers can be resource-intensive, requiring substantial in-house expertise. ProRail's decision to opt for a single supplier for the CSS was influenced by these practical constraints.

2.2.1. Opting for one supplier

ProRail's decision-making process regarding vendor lock-in reflects a careful balance of short- and long-term benefits. While the idea of soliciting bids from multiple suppliers had its appeal, ProRail ultimately opted for a single supplier due to several critical factors, including limited internal capacity and the complexities associated with managing multiple development tracks simultaneously. This strategic choice aimed to streamline communication channels, expedite problem resolution, and focus resources on improved supervision and oversight, thereby enhancing the efficiency and effectiveness of the program.

Choosing a single supplier has clear advantages. It simplifies coordination efforts, reduces administrative burdens, and facilitates more cohesive program management. With one supplier, there is a singular point of contact, which streamlines the flow of information and decisions. This arrangement can lead to faster issue resolution and more coherent program progression. However, this approach is not without its risks. A significant potential downside is the increased vulnerability to vendor lock-in, where dependence on a single supplier could limit flexibility and increase costs in the long term.

To mitigate these risks, ProRail has emphasized the importance of robust contractual protections and fostering a cooperative relationship with the chosen supplier. The strength of these contractual agreements lies in their ability to safeguard ProRail's interests, ensuring that the supplier remains accountable and that there are mechanisms in place to address any issues that may arise during the program lifecycle. This cooperative relationship is also crucial, as it builds mutual trust and understanding, which are essential for navigating the complexities of such a large-scale infrastructure program.

After deciding to work with a single supplier, ProRail initiated a carefully planned tendering process that went beyond traditional procurement methods. The focus was not solely on securing the lowest price but rather on developing a mutually beneficial partnership. This approach was essential for ensuring the long-term success of the program. The tendering process involved several rounds of dialogue with potential suppliers, during which ProRail sought to identify a partner who not only had the technical expertise but also shared its vision for successful collaboration and was committed to mitigating the risks associated with vendor lock-in.

In the end, Thales was selected as the preferred supplier. Thales demonstrated compatibility with ProRail's cooperative culture. The collaboration was formalized through a specific collaboration agreement that emphasized cooperative decision-making, knowledge sharing, and detailed risk-reduction plans. This agreement set the foundation for a strong, productive partnership aimed at the long-term success of the CSS program.

ProRail has implemented a comprehensive contract strategy designed to support a systematic and staged implementation process, coupled with ongoing system maintenance. The primary contract covers an initial eight-year period focused on development and delivery, with options to extend by two years to effectively manage any potential delays. Additionally, ProRail has established specific contracts for each railway section, which can last up to 25 years, covering both delivery and maintenance phases. This approach ensures that each segment of the railway system receives dedicated attention and maintenance, promoting sustainability and operational efficiency.

Importantly, ProRail maintains the option to terminate these section-specific contracts after ten years, with the possibility of extending in five-year increments. This flexibility is crucial for addressing the evolving needs of central system components and allows ProRail to suspend or terminate services that are no longer necessary. This contractual design provides ProRail with the agility to adapt to changing circumstances and technological advancements, ensuring the long-term viability of the CSS program.

ProRail's strategic measures are meticulously designed to cultivate a competitive market for future upgrades and ongoing maintenance, thereby securing the program's sustainability over the long term.

Understanding the occurrence, impact, and mitigation strategies of vendor lock-in is essential to appreciate the complexities and risks involved in large-scale infrastructure programs like the ERTMS program. The next chapter will provide a comprehensive background on vendor lock-in, drawing insights from both the infrastructure sector and other industries to construct a conceptual model that will guide further analysis and strategy development.

3. Background

The following background section is divided into two parts. The first part focuses on the occurrence of vendor lock-in and its impact, resulting in a conceptual model. The second part of the background section explores the causes, risks, and consequences of vendor lock-in based on literature from various sectors outside the infrastructure sector, resulting in a vendor lock-in framework. Subsequently, the vendor lock-in framework will be integrated into the conceptual model to conclude in which way they interact with each other.

3.1. Occurrence of Vendor Lock-In

Vendor lock-in arises from the dynamics between a client and a supplier of a product or service. This phenomenon can be understood through two primary components: contractual and relational.

3.1.1. Contractual Dynamics

At the contractual level, the structure and terms outlined in the agreement dictate the formal engagement between the client and the supplier. Contracts that incorporate flexibility to adapt to changing circumstances or, conversely, stringent terms that bind the parties tightly can significantly influence the likelihood and impact of vendor lock-in.

Flexible contracts often contain clauses that allow for adjustments based on evolving program requirements, technological advancements, or changes in market conditions. These contracts can reduce the risk of vendor lock-in by providing exit strategies or renegotiation terms. For example, the use of clauses such as termination for convenience, benchmarking, and periodic re-evaluation of terms can empower clients to switch suppliers or renegotiate terms without excessive penalties (Harris et al., 1998). Conversely, rigid contracts with stringent terms can entrench a client, making it difficult to transition away from the incumbent supplier without incurring significant costs or operational disruptions.

Clients with prior experience of vendor lock-in are likely to implement specific contractual strategies aimed at mitigating such risks. These strategies may include detailed service level agreements (SLAs), performance guarantees, and penalties for non-compliance (Demirel et al., 2017). For instance, in the IT sector, it is common to include clauses that mandate data portability and interoperability standards, ensuring that clients can transfer their data seamlessly to another provider if needed.

3.1.2. Relational Dynamics

On the relational side, the nature of the interaction between the client and supplier can either exacerbate or alleviate the constraints imposed by the contract. A strong, positive relationship, often built on a history of past collaborations, can lead to better alignment and reduced friction. Effective communication, mutual trust, and a collaborative approach to problem-solving can significantly mitigate the risks associated with vendor lock-in (Kern et al., 2006).

Conversely, a troubled relationship might deepen the challenges of vendor lock-in, making it difficult to achieve contract objectives efficiently. This dynamic can create a feedback loop where poor performance due to vendor lock-in further strains the relationship, potentially leading to a vicious cycle of deteriorating program outcomes.

The historical context of the relationship between the client and supplier also plays a crucial role. Decisions made in the past, based on previous experiences with vendor lock-in or the

outcomes of past programs, can influence current contract strategies and relationship management approaches (Bahli & Rivard, 2003). For instance, a client who has faced challenges with vendor lock-in in the past might prioritize building relationships with multiple suppliers to avoid over-reliance on a single provider. These historical interactions help shape the expectations and strategies of both parties, influencing how they manage the potential for lock-in.

3.1.3. External Factors

External factors also exert an influence on contract performance. Market dynamics, such as the availability of alternative suppliers or economic conditions affecting supply chains, can impact the degree to which vendor lock-in affects the program. For example, in periods of economic downturn, the scarcity of suppliers can exacerbate vendor lock-in, as clients have fewer alternatives to turn to (Maley et al., 2015).

Technological advancements and regulatory changes can also play a significant role. The advent of new technologies might provide clients with more options and reduce dependency on a single supplier. Regulatory frameworks, such as those promoting open standards and interoperability, can also mitigate the risks of vendor lock-in by ensuring that clients are not unduly constrained by proprietary technologies or practices.

The resilience of the contractual and relational dynamics to these external pressures determines the overall stability and success of the program. A well-structured contract coupled with a strong, cooperative relationship can help withstand external shocks, maintaining program continuity and performance.

3.1.4. Conceptual Model

This intricate interaction between contractual and relational levels, influenced by historical context and choices made earlier in the contract, is illustrated in a conceptual model (Figure 2). This model demonstrates how these elements interrelate and impact the manifestation of vendor lock-in. The historical context and choices made by both parties influence this interaction, affecting how vendor lock-in manifests. This, in turn, impacts the ultimate contract performance, which external factors such as market dynamics can further influence. The resulting contract performance creates a feedback loop, continually shaping the client-supplier interaction.

For instance, when external factors negatively impact contract performance, this can create a feedback loop that deteriorates the relationship between the client and supplier. Such deterioration further heightens the risk of vendor lock-in, potentially leading to a vicious cycle where each negative outcome reinforces further constraints and dependencies in the relationship. Conversely, when the contract performs well due to favourable conditions and effective management, it fosters a positive feedback loop. This enhances the relationship between the parties, reducing the risk of vendor lock-in as mutual trust and reliability strengthen the partnership.

This dynamic interaction illustrates the critical role of relational dynamics in contract management, highlighting how positive and negative feedback loops directly influence the risk of vendor lock-in. These relationships and their implications will be explored in greater detail in the following section, emphasizing the significant impact that relational dynamics can have.

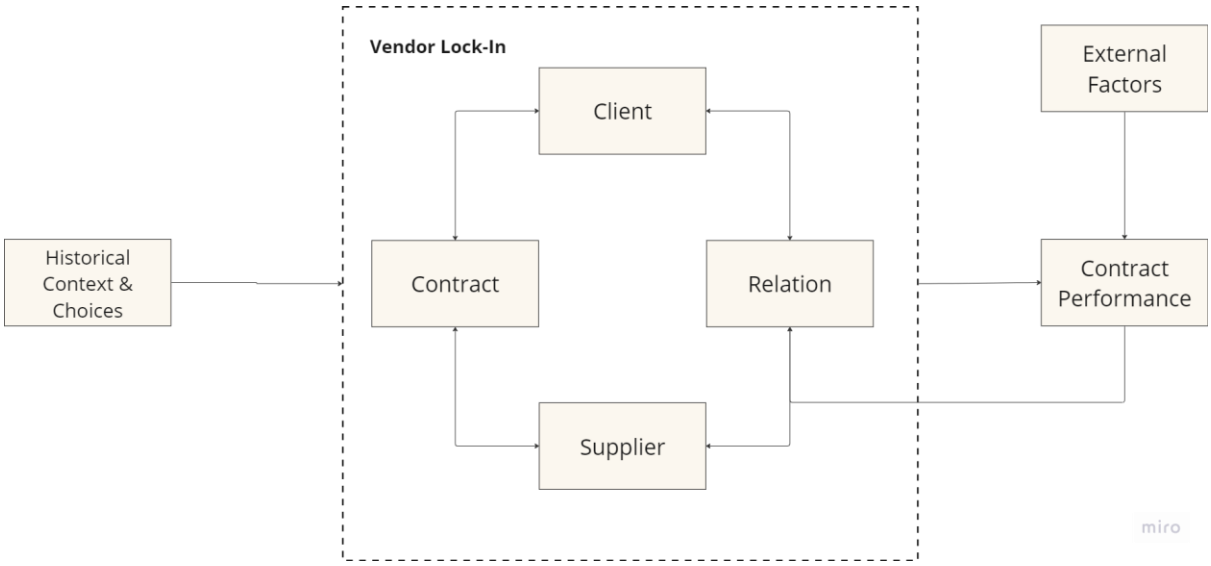

Figure 2: Conceptual Model Occurrence of Vendor Lock-In

3.2. Causes, risks and effects of Vendor Lock-In

This section delineates a theoretical framework drawn from literature within outsourcing sectors, providing insights into the causes, risks, and consequences of vendor lock-in. The theoretical framework begins by elucidating the reasons behind the occurrence of vendor lock-in. Utilizing the Kraljic Matrix, this section delineates how complexity within infrastructure programs can bind a client to a particular supplier. By categorizing purchased materials and services based on supply risk and consumption value, the Kraljic Matrix offers a structured approach to understanding the dynamics that contribute to client-supplier dependencies.

Following the exploration of the causes, the theoretical framework delves into the risks that may arise from being bound to a specific supplier. These risks are classified into two primary categories: market dynamics and supplier behaviour. Market dynamics encompass the complexities of market conditions, including monopolistic tendencies and high entry barriers, which may exacerbate the client's reliance on a single supplier. On the other hand, supplier behaviour examines how the actions and strategies of suppliers can further entrench client dependence and limit flexibility within the relationship.

3.2.1. Supplier Dependency

The complexity inherent in significant infrastructure programs necessitates a re-evaluation of collaborative approaches. Unlike traditional single-focus projects, these programs entail a series of interconnected projects with distinct timelines and stakeholders. This dynamic nature calls for a departure from conventional contract types prevalent in the infrastructure industry (Frederiksen et al., 2021).

Traditional project-specific contracts struggle to accommodate the multifaceted lifecycle of programs. Attempting to manage the diverse actors and requirements of development, delivery, and maintenance within a single, overarching contract often leads to complications and misunderstandings (Arnoldussen et al., 2017). In response to this programmatic complexity, framework agreements emerge as a viable solution, offering a more adaptable approach to contractual governance.

Framework agreements provide flexible frameworks that can evolve with a program's changing needs over its lifecycle, unlike traditional contracts. This adaptability is essential for the long-term commitment required in complex undertakings. By fostering stable collaboration with selected suppliers, framework agreements guide programs from initial development stages through ongoing maintenance. This shift from project-specific contracts to programmatic frameworks recognizes the dynamic nature of program execution and addresses the limitations of traditional approaches, facilitating long-term collaboration and aligning stakeholders' understanding of program goals and objectives (Vosman, 2020).

As infrastructure programs grow increasingly complex, the adoption of framework agreements becomes imperative for successful development and implementation. These contracts support effective long-term development, delivery, and maintenance. Throughout the program lifecycle, clients heavily rely on supplier expertise (Opara-Martins et al., 2016). Changes in program suppliers can be disruptive and expensive, requiring large sums of money to be spent on knowledge transfer and threatening the sustainability of the program. Consequently, clients often find themselves intricately linked to their chosen supplier, reflecting a dependency that characterizes infrastructure programs marked by high complexity.

This intricacy not only influences program dynamics, it also reshapes market conditions. The intricate relationship between complexity and competition within infrastructure programs necessitates a comprehensive framework for understanding and mitigating the risks of vendor lock-in. The Kraljic Matrix (Kraljic, 1983) provides a valuable tool for outlining this relationship, categorizing purchased materials and services based on supply risk and consumption value. By analysing program needs through this lens, valuable insights into potential vendor lock-in risks associated with different purchase categories can be gained.

This matrix categorises purchased materials and services into four quadrants based on two key factors: supply risk (the ease or difficulty of obtaining a particular good or service) and consumption value (the strategic importance and financial impact of the purchase on the client's operations). By analysing a program's needs through the lens of the Kraljic Matrix, clients can gain valuable insights into potential vendor lock-in risks associated with different categories of purchases. This matrix includes four types of items (Figure 3).

- Leverage items: low supply risk, high consumption value.
- Non-critical items: low supply risk, low consumption value
- Strategic items: High supply risk, high consumption value
- Bottleneck items: High supply risk, low consumption value.

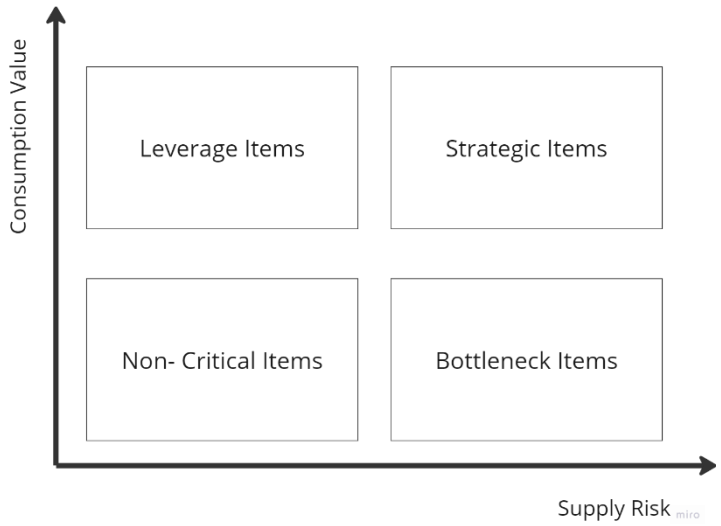

Figure 3: Kraljic Matrix that outlines the relation between consumption value and supply risk (Kraljic, 1983)

Two Kraljic Matrix quadrants are especially relevant to the issues concerning vendor lock-in in infrastructure programs, strategic and bottlenecks items:

Strategic Items: These products or services are characterised by high supply risk and profit impact. In the context of infrastructure programs, this could encompass highly specialised equipment, customised software solutions, or the expertise of a niche contractor with extensive experience in a particular construction technique. The program's success hinges on these strategic products reliable supply and performance, making them prime candidates for vendor lock-in if alternative suppliers are scarce.

Bottleneck items: These products or services have a high supply risk and a low-profit impact. They might include essential materials with volatile market prices, limited production capacity, or geographically restricted availability.

These high-risk categories within the Kraljic Matrix become particularly troublesome when considering the monopolistic markets that often characterise complex infrastructure programs. The high entry barriers associated with complexity – the need for substantial investments in research and development, sophisticated technology, and highly skilled personnel – limit the pool of qualified suppliers (Karakaya & Stahl, 1989). This lack of competition strengthens the position of incumbent suppliers, potentially leading to situations where clients become reliant on a single vendor, especially for strategic and bottleneck items adapted from the Kraljic (1983) Matrix. This adds high entry levels as an extra facet of complexity, leading to being bonded to a supplier.

The complexity of infrastructure programs also contributes significantly to high switching costs, further solidifying vendor lock-in. Transitioning to a new supplier requires finding a qualified alternative and incurring significant expenses:
Building a new working relationship with a different supplier requires time and resources to establish communication channels, define expectations, and ensure a smooth knowledge transfer (Aubert et al., 2005). The program's intricacies, design specifications, and accumulated knowledge specific to the program must be effectively transferred to the new supplier, potentially leading to delays and rework.
Program elements may need to be redesigned to accommodate the new supplier's expertise or technology, further adding to the complexity and cost of switching.

The program's intricate complexities and the limited pool of qualified suppliers in a monopolistic market make switching vendors difficult and expensive, particularly for strategic and bottleneck items.

The intricacies of infrastructure programs create a strong bond with suppliers, evidenced by three key facets: high switching costs, high entry levels, and the utilization of framework agreements. These complexities highlight the importance of effective contractual governance and strategic supplier management. Transitioning to an examination of market dynamics risks, it becomes clear that while framework agreements address certain complexities, the evolving landscape of digitalization and IT integration introduces additional layers of intricacy that demand careful consideration.

3.2.2. Market Dynamics

Building upon the framework established by complexity, the next section delves into the specific risks associated with vendor lock-in caused by this supplier dependency. As outlined, framework agreements have been adopted due to the complexity of infrastructure programs. These agreements foster long-term partnerships with qualified suppliers who can navigate the intricate challenges of these undertakings. However, the rise of digitalisation and IT integration in infrastructure adds a new layer of complexity.

This digital transformation will increase complexity. Infrastructure programs will rely more on advanced technologies, tailored software solutions, and interconnected systems. This presents a challenge for clients (Favoretto et al., 2021).

On the one hand, digitalisation offers significant benefits in the infrastructure sector, such as improved efficiency, enhanced safety, and real-time monitoring (Bonci et al., 2019). However, integrating complex IT systems often results in each supplier using their technology, creating a unique product specific to that supplier. This can make it difficult and expensive to switch vendors in the future (Favoretto et al., 2021). For example, a highly specialised rail control system critical to the operation may be intricately linked to a specific supplier's proprietary software. Transitioning to a new supplier would require finding a qualified alternative, which could lead to redesigning system elements or replicating complex software functionalities in-house, resulting in significant costs.

This digital transformation highlights the need for a deeper understanding of vendor lock-in in infrastructure programs These large-scale programs increase the risks associated with vendor lock-in. The size and complexity of programs make changing vendors even more disruptive and costly. Additionally, the limited number of qualified suppliers for such large programs can further restrict the market, reducing competition and giving existing suppliers more bargaining power.

The rail sector illustrates this dynamic. Rail programs are complex, with strict safety regulations and high entry barriers (Beck, 2011). These factors contribute to a market that is already sensitive to vendor lock-in. Integrating advanced digital technologies into rail infrastructure, from automated train control systems to sophisticated maintenance diagnostics, further exacerbates this issue. Clients in the rail sector face the challenge of balancing the need for innovative technologies with the risk of becoming overly reliant on a single supplier.

The novelty of programmatic approaches in infrastructure programs coincides with a rise in vendor lock-in concerns. This research addresses this gap by focusing on a literature review of

sectors where vendor lock-in is a well-established phenomenon – specifically those utilising outsourcing. Literature confirms that increased outsourcing within an industry often leads to a vendor lock-in effect (Maley et al., 2015; Powell, 1992). In sectors like process and IT, where companies entrust various business activities to external service suppliers, vendor lock-in is a common problem.

While outsourcing offers benefits like cost reduction, flexibility gains, faster development cycles, and accounting advantages (Clemons, 2001), it also introduces significant risks.

A closer examination of the IT sector reveals the pitfalls of vendor lock-in. Once a complex IT contract is signed, clients may have limited options beyond sticking with the initial vendor. This reduced flexibility can stem from various factors (Quixy, 2023):

- High investments in customised equipment: Equipment tailored explicitly to a vendor's software can create a dependency, making switching costly and disruptive.
- Loss of asset ownership: Outsourcing critical assets can leave clients reliant on the vendor's infrastructure, hindering their ability to switch suppliers.
- Erosion of internal expertise: Outsourcing internal staff and knowledge transfer can make companies overly dependent on the vendor's expertise, limiting their ability to manage the relationship effectively.

Beyond reduced flexibility, vendor lock-in in IT often manifests as:

- High switching costs: Migrating to a new solution can be expensive due to data migration, system reconfiguration, and retraining personnel.
- Limited compatibility: Proprietary systems that lack compatibility with other solutions can hinder a client's ability to switch vendors.
- Reduced innovation: Over-reliance on a single vendor can stifle innovation as clients become accountable to the vendor's roadmap.
- Contractual constraints: Long-term agreements with specific terms and conditions can limit a client's bargaining power and flexibility.
- Data ownership concerns: Vendor data ownership can restrict a client's control and access to critical information.

Regardless of the specific concerns, the outcome is a reduction in the client's bargaining power, as failing to meet the vendor's demands could lead to an unacceptable loss of revenue or profits (Lonsdale, 2001).

A prominent concern in the process industry revolves around vendor lock-in arising from increased dependence on outsourcing partners (Maley et al., 2015). This growing reliance creates uncertainty and potential conflict within these partnerships. The risks of lock-in intensify when the pool of qualified suppliers is limited and the client lacks expertise in managing outsourcing contracts (Aubert et al., 1998). Strategies to mitigate vendor lock-in in this sector involve careful consideration of contract clauses related to termination, asset buy-back, handover obligations, and intellectual property rights (Bahli & Rivard, 2003). Significantly, studies within the process industry often cite the IT sector when investigating lock-in scenarios, suggesting the possibility of sharing mitigation strategies between different industries. This presents a compelling opportunity to explore the application of these strategies within infrastructure programs.

This cross-industry referencing highlights the potential to adapt existing theories and strategies from well-established outsourcing sectors to the challenges of the infrastructure sector. Transaction cost economics and agency theory, both prominent in IT outsourcing research, offer valuable frameworks for understanding lock-in scenarios (Harris et al., 1998; Williamson, 1985).

Transaction cost economics rests on two core behavioural assumptions. The first principle is bounded rationality, which recognises that people cannot consider every outcome when making decisions because of their cognitive limits (Williamson, 1985). This affects clients because they might struggle to clearly state what they need, choose the right vendors, or manage these relationships well.

The second tenet of transaction cost economics is opportunism, which suggests that individuals may act in their self-interest, potentially engaging in cunning behaviour. IT vendors, for example, might exploit a client's lack of experience or understanding by misrepresenting their capabilities or leveraging their knowledge advantage to sell overpriced resources (Kern et al., 2006).

Although vendor lock-in is a significant concern in outsourcing agreements, agency and transaction cost theory point to a broader range of issues (Bahli & Rivard, 2002):

Costly contractual amendments:
Changes made to outsourcing agreements in the middle of a project or program can be expensive. Budgets can be severely strained, and program progress is hampered by renegotiation costs and the possibility of disrupting ongoing operations (Aubert et al., 1998). Firmly structured contracts can make adjusting for unforeseen events or changing program requirements more complex.

Unexpected transition and management costs:
Transitioning from internal operations to an outsourced service can involve more complex and costly steps than first expected (Hirschheim & Lacity, 2000). Process realignment, system integration, and knowledge transfer can all lead to unexpected complications. Moreover, committed resources are needed to continuously manage the outsourced relationship to guarantee efficient operation and performance optimisation.

Disputes and litigation:
Disagreements with the outsourcing vendor can disrupt the established workflow and necessitate significant resolution of resources (Willcocks & Lacity, 2009). These disputes can stem from various factors, such as differing interpretations of contract terms, performance issues, or disagreements over service level expectations. Furthermore, unforeseen legal or regulatory changes can disrupt the outsourcing arrangement and necessitate service delivery or contractual framework adjustments. Exploration of further outsourcing difficulties underscores the complexity of these alliances. This study will focus on vendor lock-in. However, an understanding must also consider the broader range of complications during outsourcing. After exploring the complexities of vendor lock-in, research has pinpointed three major risk factors that support this phenomenon: 1) Asset specificity, 2) number of suppliers and 3) lack of client expertise (Bahli & Rivard, 2003).

1. *Asset Specificity*

The first factor centres on the concept of asset specificity. This refers to investments made especially for the goods or services offered by a specific vendor. These investments may include specialised employee training on the vendor's system, custom software for the vendor's platform, or specialised hardware to work harmoniously with the vendor's product. If the client chooses to move vendors, these assets become much less valuable. This can cause significant financial losses for both the departing client and the vendor (Kern & Dhillon, 2002).

The outsourced operation's complexity increases this risk. Even experienced vendors may need to make specialised investments to deliver the service when a client's needs call for a highly customised environment. This strengthens the client's bond with the current vendor by raising the degree of asset specificity (Kern & Dhillon, 2002).

2. *Number of Suppliers*

The second potential source of risk stems from a restricted group of capable suppliers. A client's ability to negotiate significantly lowers when only a few vendors offer a specific good or service (Williamson, 1985). The client is put in a precarious situation because of the absence of alternatives. Gainful contract negotiations or vendor switching become complex tasks. Aware of this, vendors might take advantage of their position by driving up costs or imposing unfair conditions on agreements, leading to vendor lock-in, which makes it challenging for the client to locate other sources (Nam et al., 1996)

3. *Lack of Client Expertise*

The final risk factor stems from the client's knowledge limitations. Clients with little knowledge of outsourcing agreements are severely disadvantaged (Bahli & Rivard, 2003). When trying to leave the partnership, they might unintentionally miss important terms about ownership of intellectual property or termination rights, which could have negative consequences. Similarly, a client's ability to accurately assess cost and quality may be hampered by a lack of experience with the outsourced operation. This increases the difficulty of breaking ties with a poor vendor providing suboptimal service (Aubert et al., 1998).

Concluding the exploration of market dynamics, the analysis identifies three critical facets: asset specificity, the number of suppliers, and the deficiency in client expertise. These facets illuminate the intricate interplay between external market conditions and the nuanced challenges inherent in managing vendor relationships within the context of infrastructure programs.

3.2.3. Client - Supplier Dynamics

While market dynamics primarily address external factors, such as market conditions and supplier availability, this section delves into the actions and strategies undertaken within client-supplier relationships. Transitioning to an examination of these dynamics, the focus shifts towards how internal interactions can significantly influence and exacerbate vendor lock-in within outsourcing arrangements.

Excessive reliance on a single supplier creates an environment conducive to opportunistic behaviour and undermines the effectiveness of well-drafted contracts (Harris et al., 1998). Agency theory examines this phenomenon by highlighting the main challenges: 1) moral hazard, 2) imperfect commitment, and 3) adverse selection (Aubert et al., 2003). When both clients and suppliers are aware of these difficulties and how to navigate them, they can more

effectively manage the complexities of their relationship and reduce the risks of opportunistic behaviour (Aubert et al., 2003).

1. *Moral Hazard*

A moral hazard arises when one party, typically the supplier, finds it difficult to closely monitor the other's activities without incurring significant expenses. This information asymmetry makes it challenging for a client to determine whether a service issue results from supplier negligence or unanticipated circumstances. Because of this information gap, a locked-in vendor could, even in situations where it is false, blame poor performance on external circumstances. Traditional instances of moral hazard encompass dishonesty, abdicating duties, manipulating expenses, or overall carelessness in providing services (Hennart, 1993).

However, moral hazard is not a one-way street. Clients can also behave opportunistically. For instance, clients could act as though they do not know and refuse to tell the supplier about impending developments, even though it was clear long before the developments were required (Tirole, 1988).

Moral hazard frequently results in the supplier exerting less effort, eventually lowering the quality of the services. It is reasonable to assume that the supplier's effort may not be maximized if the contract does not explicitly define performance levels. The actual quality of service depends on how accurately it is measured and how easily these measurements can be verified, even with well-defined performance targets. As a result, the clarity of the contractual terms is linked to the quality of the services.

2. *Imperfect commitment*

Imperfect commitment underscores both clients' and suppliers' inherent constraints in fully fulfilling their contractual obligations. This concept recognizes that, despite good intentions, unexpected events or strategic reasons might force parties to break their promises. For instance, a client may withhold payment for rendered services, citing financial constraints or disputing unexpectedly high costs. Conversely, a supplier may neglect to deliver services as agreed, contending that specific requirements were unforeseen or that the contract lacked clarity regarding obligations.

This challenge is a common risk in contractual agreements and is not specific to any contract. Developing contracts with precise terms and integrated dispute-resolution procedures is essential to addressing imperfect commitment. Furthermore, building a relationship based on mutual respect through open communication can help reduce the risks associated with imperfect commitment by ensuring that both parties continue to adhere to the terms of the agreement.

3. *Adverse selection*

Adverse selection occurs when a client cannot accurately evaluate a potential supplier's attributes or confirm the veracity of its claims. This informational asymmetry may make it difficult for the client to choose a suitable supplier, leading to collaboration with a vendor with higher risks. Clients in outsourcing contracts frequently must make choices based on scant information. Since all suppliers will inevitably want to brag about their experience, it is up to the client to look past these declarations and consider other markers of a supplier's track record of dependability and performance.

To reduce the risks of adverse selection, clients can use various strategies, such as conducting thorough due diligence, seeking independent third-party evaluations, or requiring

demonstrations of the supplier's capabilities. These strategies can help clients better understand potential suppliers' quality and make more informed decisions. This, in turn, can reduce the likelihood of entering a disadvantageous contract with a supplier that may not meet the program's needs or expectations. A thorough examination is essential to ensure the client does not unintentionally become locked in with an inadequate vendor.

However, when vendor lock-in remains unchecked, it can provide fertile ground for the manifestation of opportunistic behaviour by suppliers, influenced by moral hazard, imperfect commitment, and adverse selection. These dynamics lead to adverse consequences for the client, characterized by service degradation and cost escalation, as outlined in the forthcoming section.

3.2.4. Consequences of Vendor Lock-In

This section delineates the two primary consequences of vendor lock-in: 1) service degradation and 2) cost escalation (Bahli & Rivard, 2003).

1. *Service degradation*

Service degradation refers to the gradual decline in the quality of services the client receives throughout the contract lifecycle. This decline can take on several insidious forms. Initially, agreed-upon service levels may not be consistently met, leading to a gradual erosion of performance (Aubert et al., 1998). In extreme cases, the vendor may prioritise other clients with more lucrative contracts, neglecting the locked-in client's needs. This decline can be particularly detrimental when the outsourced service directly impacts the client's core operations. When maintenance services decline, a critical manufacturing process may be affected, potentially resulting in production delays and lost revenue. Moreover, finding substitute suppliers who can step in fast and provide the required service quality is challenging due to the restricted supplier options frequently connected to vendor lock-in.

2. *Cost Escalation*

Cost escalation signifies the unforeseen increase in expenses incurred by the client over the contract period. Vendor lock-in can result in a situation where the client has little power to negotiate advantageous pricing during contract renewals, even though initial negotiations set a baseline cost. Significant price increases are frequently the result of this lack of bargaining power, commonly caused by asset specificity or a small pool of qualified vendors. (Aubert et al., 2003) provide an example of a public company that is compelled to accept a 50% cost escalation for an essential service due to its deficiency in internal expertise and limited alternative suppliers. This illustrates how vendor lock-in can impose significant financial strain on unsuspecting clients.

3.2.5. Vendor Lock-In Framework

In the preceding sections, the literature has elucidated the causes of supplier dependency, resulting in a client's bond to a particular supplier through framework agreements, high entry levels, and high switching costs. As digitalization continues to permeate industries, these risks become even more pronounced. Within the literature from various sectors, these risks are categorized into two groups: market dynamics and supplier behaviours.

Market dynamics encompass factors such as asset specificity, the number of suppliers, and the lack of client expertise. Supplier behaviour, on the other hand, introduces the risk of

opportunism, which can manifest through moral hazard, imperfect commitment, and adverse selection – as identified in extant literature.

When these risks remain unchecked or inadequately addressed, they can lead to two primary consequences of vendor lock-in: service degradation and cost escalation. This flow of causation is depicted in Figure 4 as a framework, outlining the interconnected nature of the causal factors, risk groups, and resulting consequences.

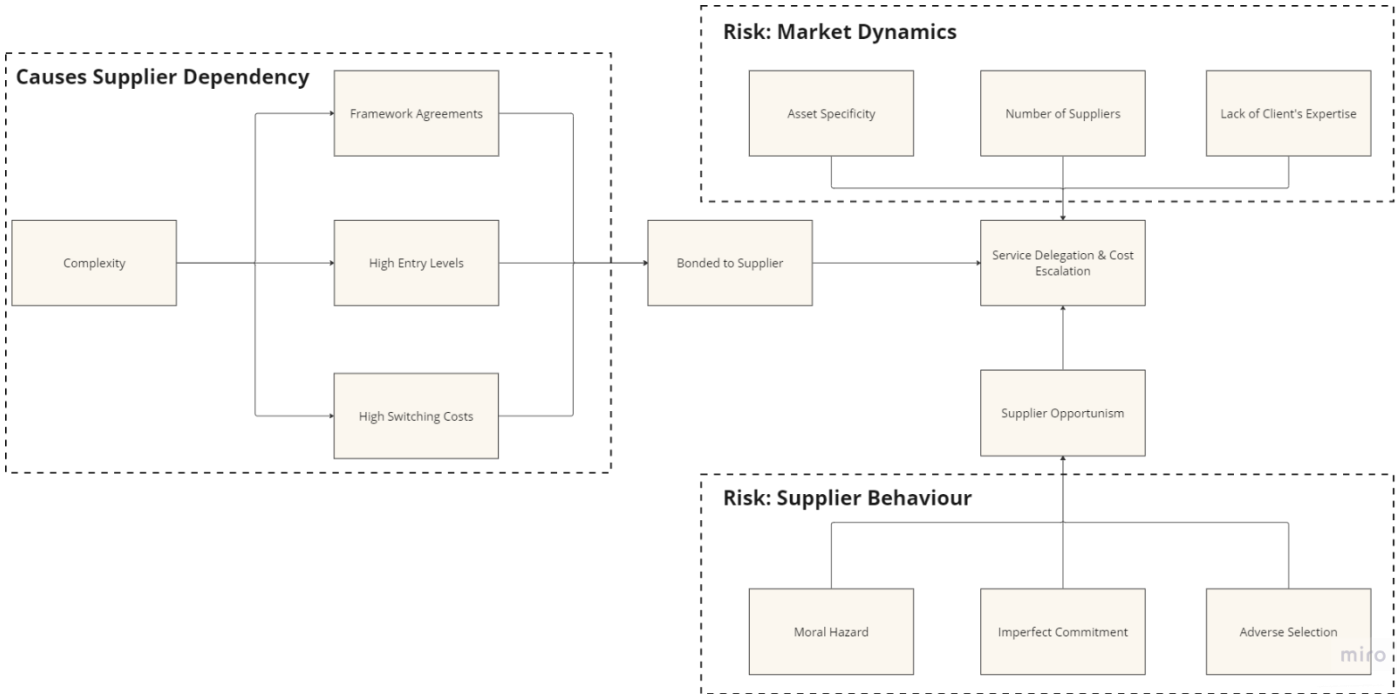

Figure 4: Vendor Lock-In Framework

3.3. Integrating Framework into Conceptual Model

This section examines how the vendor lock-in framework, detailed in previous discussions, integrates into the overarching conceptual model introduced earlier in the document.

The framework's discussion of the causes of vendor lock-in, such as contractual rigidity and strategic dependency on specific suppliers, can be directly linked to the conceptual model's emphasis on contractual dynamics. These causes explain the underpinnings of vendor lock-in within the model, detailing how contractual terms and supplier choices influence the relational aspects of infrastructure programs. The identified risks, categorized into market dynamics and supplier behaviour, provide a deeper insight into the external and internal pressures that influence vendor relationships. By integrating these risks into the conceptual model, the model not only illustrates these pressures but also highlights their potential to disrupt contract performance and escalate vendor lock-in scenarios. The effects of vendor lock-in, notably service degradation and cost escalation, represent critical outcomes that can stem from poor management of vendor relationships. These effects are integrated into the conceptual model by showing their direct impact on program outcomes and their role in perpetuating negative feedback loops within client-supplier interactions.

With this knowledge in place, it becomes feasible to examine a case study, focusing particularly on the mitigation strategies employed to address these challenges. This case study will provide

practical insights and real-world examples of how organizations navigate the intricacies of vendor lock-in and implement measures to mitigate its adverse effects.

The methodology section that follows will detail the approach taken to conduct this examination. It will outline the research design, data collection methods, and analytical techniques used to investigate the case study. By explaining the methodological framework, a clear roadmap for understanding how the study was conducted will be offered, ensuring transparency and rigour in the examination of vendor lock-in mitigation strategies. This will set the stage for a thorough and insightful analysis in the subsequent results section.

4. Methodology

This chapter outlines the methodological approach adopted to investigate the vendor lock-in situation within the Central Safety System contract for the ERTMS program.

4.1. Research Design

This research uses a single-case study approach (Gustafsson, 2017) to examine the CSS contract in the context of the ERTMS program. This approach allows for a detailed analysis of vendor lock-in and provides valuable insights into contractual dynamics and challenges. However, it is essential to recognise this approach's limitations, particularly in generalisability (Willis, 2014).

Due to several advantages, a single-case study approach was adopted for examining vendor lock-in situations. This method enabled a comprehensive exploration of all relevant facets related to vendor lock-in, uncovering the dynamics, challenges, and implications associated with the problem (Gustafsson, 2017). Gaining such a comprehensive perspective was essential for formulating effective strategies to address vendor lock-in within the infrastructure sector.

The choice of the CSS contract as the focus of this study is due to its strategic significance within the infrastructure sector's transition towards programmatic approaches. In addition, the CSS contract's framework agreement addresses a significant gap in the literature regarding the risks associated with such contractual arrangements. This research aims to provide actionable insights and sector-wide recommendations for mitigating vendor lock-in risks within framework agreements by examining this case study.

4.2. Data Collection Methods

A multifaceted data collection strategy was implemented, which included document analysis, interviews, and expert panel validation. Using a triangulation process facilitated the identification of overarching themes and relationships, enriching the analysis and interpretation of the data (Noble & Heale, 2019).

4.2.1. Document Analysis

The research started with analysing the CSS contract, agreements, and strategic documents to identify incentives contributing to or alleviating vendor lock-in. The evaluation focused on how effectively the contract addresses challenges related to vendor lock-in. The following documents were analysed as part of this process:

- *Reconsideration of Two System Suppliers in Infrastructure:*
  This document offers additional insights into the ramifications of selecting between two system suppliers for infrastructure programs, providing valuable considerations to aid decision-making.

- *Procurement and Contracting Strategy:*
  This document outlines objectives for procurement and contracting and emphasises aspects such as value-for-money, service continuity, future resilience, and comprehensive management.

- *Contracting Plan for CSS System Supplier for ERTMS:*
  Crucial for the ERTMS program's implementation and maintenance phases, this plan details the contracting process for the CSS System Supplier, aligning with overarching contracting strategies.
- *Explanation of the Tender Documentation for CSS for ERTMS between ProRail & Thales:*
  This document clarifies the contract's requirements and specifications by detailing ProRail's vision, context, and essential activities for successful system implementation and management.
- *Framework Agreement for CSS for ERTMS between ProRail and Thales:*
  This agreement establishes the terms governing hardware, software, services, and program execution, providing the foundational framework for the CSS program between ProRail and Thales.
- *Collaboration Agreement for CSS for ERTMS between ProRail and Thales:*
  Outlining the intended collaboration between ProRail and Thales, this agreement sets the stage for joint efforts and solutions within the contractual framework.
- *General Procedures for CSS for ERTMS between ProRail & Thales:*
  This document is categorised into work packages and details objectives, activities, process requirements, product specifications, inputs, and deliverables for effective program execution.
- *Contract Management Plan:*
  Outlining program-specific aspects, contract management strategy, risks, opportunities, and organisational and communication frameworks, this plan guides the execution phase of the CSS for the ERTMS agreement.

The research aimed to comprehensively understand the contractual framework, procurement strategies, and collaborative efforts involved in implementing the CSS for the ERTMS program by analysing these documents.

4.2.2. Interviews

The interviews aimed to gain insights from IT-sector experts and CSS stakeholders about vendor lock-in issues in the CSS contract. Nine qualitative, face-to-face, in-depth interviews were conducted with IT-sector experts and current or former stakeholders involved in the CSS contract. The selected methodology aimed to combine structure and flexibility (Legard et al., 2003) to effectively address the challenge of vendor lock-in. This approach allowed for thorough exploration, probing and examination of responses while also enabling the researcher to be responsive to spontaneously raised, pertinent issues during the interviews.

The interviews with IT experts provided insights into their comprehension of vendor lock-in and their experiences addressing it. The primary focus was on identifying overarching strategies applicable beyond IT to enhance relevance within the infrastructure sector. These interviews delved into best practices and lessons learned from prior encounters with vendor lock-in scenarios. Conversely, stakeholder interviews concerning the CSS contract post-contractually scrutinised emotions, opinions, and behavioural aspects associated with the ProRail and Thales relationship. This investigation also aimed to understand the importance of these relationships, core values, and the elements that promote successful collaboration.

The stakeholders interviewed for this study included various groups. These comprised the contract management teams of Thales and ProRail, who were directly involved in the collaboration. Additionally, representatives from the company P2, enlisted by ProRail to facilitate and advise on the partnership between Thales and ProRail, were part of the interview pool. Moreover, individuals associated with the procurement strategy and indirectly connected to the ERTMS program were included. This group encompassed a procurement strategist and an overarching ERTMS program manager.

Although in-depth interviews offer opportunities to gather insightful information, it is essential to remain mindful of potential risks and constraints. To mitigate these risks, a structured interview guide was developed to maintain focus on the research question and reduce the risk of deviation from the primary objectives. In addition, standardised follow-up questions were included to ensure consistency. A general question list of the interviews is given in Appendix I. The interviewees received the interview plan before the start to ensure effectiveness and address any issues or deviations from the research goals beforehand.

Overall, the interview process was dynamic and responsive, allowing for exploring and formulating additional questions based on the interviewees' responses. This adaptability ensured the interviews covered relevant topics in depth while adjusting to each interviewee's perspectives.

The interviews were conducted with the following participants:

- Five intern CSS Contract Stakeholders
- Three extern CSS Contract Stakeholders
- One IT-Sector Expert

Table 2 provides an overview of the interviews, including companies, the role of the interviewee, the date and day, time, and location.

Table 2: Interview Schedule

	Type	Company	Role	Date
1	CSS Intern	ProRail	Integral Contract Manager	15-1-2024
2	CSS Intern	Thales	General Project Manger	15-1-2024
3	CSS Intern	ProRail	Contractmanager	16-1-2024
4	CSS Intern	Thales	Contract Manager, Commercial Manager	16-1-2024
5	IT Extern	RET	Manager IT	17-1-2024
6	CSS Extern	ProRail	Contractmanager during Procurement	18-1-2024
7	CSS Extern	Prorail	Purchasing strategist Train safety system	18-1-2024
8	CSS Extern	PD	Program Manager	19-1-2024
9	CSS Intern	P2	Collaboration manager	22-1-2024

By incorporating both internal and external CSS Contract stakeholders along with an IT-Sector Expert, the study benefits from a wide range of perspectives, enhancing the richness and relevance of the data. A structured interview guide with standardized follow-up questions ensures consistency and focus, while the dynamic nature of the interviews allows for adaptability, enabling the exploration of emergent themes based on interviewee responses. Providing interview plans in advance prepares interviewees to offer detailed insights, enhancing the effectiveness of the data collection.

4.2.3. Expert Panel

In this phase, experts convened to validate and offer feedback on the developed theoretical framework applied to the case study to ensure its accuracy and relevance (Saunders et al., 2007). The panel comprised stakeholders from Thales and ProRail, encompassing diverse perspectives for a comprehensive assessment of contract dynamics. Additionally, a participant from the University of Twente contributed academic expertise to the deliberations.

Representatives from ProRail, Programma Directie ERTMS (PD), Thales, and the University of Twente constituted the group of five people. An external session with the commercial manager of Thales before the expert panel added valuable insights and served as a test for the actual expert panel. The primary objective of the panel was to evaluate the theoretical framework's applicability to the infrastructure sector, ensuring its alignment with real-world scenarios. The researcher guided the session to maintain the study's direction and was assisted by its supervisor, who took notes and provided comments.

During the session, six propositions emerged from applying the conceptual framework to the CSS case study, realising extensive discussions among participants. These propositions, including assertions like 'ProRail intentionally engages in a Vendor Lock-In situation with Thales,' underwent thorough examination, offering insights into the intricate dynamics of vendor lock-in within the CSS contract context. The introduced propositions are given in Appendix II.

The expert panel provided invaluable feedback on the conceptual framework, pinpointing areas for potential revision. This process aimed to refine the framework, optimising its efficacy in analysing and mitigating vendor lock-in challenges within the infrastructure sector. The discussion sessions had a maximum timeframe of eight minutes for every proposition, fostering focused and productive discussions while maximising efficiency.

4.3. Data Analysis

This section explains how the collected data was analysed to understand the dynamics of vendor lock-in within the CSS contract. Analytical techniques were applied to each data source to explore and interpret the findings thoroughly.

In the initial phase, a document analysis was conducted to examine the collected documents meticulously. Each document was carefully reviewed to find important information about the contractual framework, procurement strategies, and collaborative efforts related to the CSS for the ERTMS program. Key themes, patterns, and insights were identified and coded to facilitate cross-referencing and synthesis of findings.

Hereafter, transcripts from the qualitative, face-to-face interviews were analysed using thematic analysis techniques. The interviews with IT-sector experts and CSS stakeholders provided rich qualitative data on their perceptions, experiences, and insights regarding vendor lock-in issues within the CSS contract. Through iterative coding and categorisation using *AtlasTI*, recurring themes and patterns emerged, shedding light on the nuances of vendor lock-in dynamics and post-contractual relationships between ProRail and Thales.

Subsequently, the findings from both document analysis and the interviews were integrated through a triangulation process (Noble & Heale, 2019). Consistencies, discrepancies, and complementary insights across different data sources were examined to develop an understanding of vendor lock-in dynamics within the CSS contract. This approach facilitated

the identification of overarching themes and relationships, enriching the analysis and interpretation of the data.

Furthermore, the feedback and insights provided by the expert panel during the validation of the theoretical framework were systematically analysed to evaluate the framework's accuracy and relevance to the infrastructure sector. Inputs from diverse stakeholders representing ProRail, Thales, and academic expertise were synthesised to refine the theoretical framework further and ensure its alignment with real-world scenarios. Through data analysis and refinement of the theoretical framework, the research aimed to generate insights and recommendations for mitigating vendor lock-in challenges within the CSS for the ERTMS program, contributing to improved contract management and collaboration practices in the infrastructure sector.

4.4. Validity

Throughout the methodological process, several measures were implemented to safeguard the validity and reliability of the research findings.

Adopting a single-case study approach focusing on the CSS contract within the ERTMS program enabled an in-depth exploration of vendor lock-in (Gustafsson, 2017). This in-depth analysis yielded rich and detailed insights into the phenomenon. Furthermore, the study employed triangulation by utilising multiple data collection methods. This included document analysis, stakeholder interviews, and expert panel validation. By cross-referencing findings from various sources, the research reduced the chance of bias or misinterpretation, making the results more reliable.

Member checking was used to make the findings more credible (Birt et al., 2016). This meant sharing early findings and interpretations with critical stakeholders in the CSS contract. Their feedback helped ensure that the research accurately reflected the details of the CSS contract dynamics and vendor lock-in challenges from their viewpoints.

The theoretical framework underwent validation by an expert panel of stakeholders from Thales and ProRail. This validation process ensured that the model accurately represented the complex interrelationships and dependencies within the CSS contract. In turn, this enhanced the trustworthiness and applicability of the research findings (Jones & Hunter, 1995).

5. Results

Building on the foundation established in the background section, this part of the text elaborates on the conceptual model and vendor lock-in framework. From the occurrence, causes, risks and consequences of vendor lock-in outlined, this section focuses on the mitigation techniques employed to counteract vendor lock-in. The mitigation techniques used in the case study will be examined and supported or criticised by outsourcing literature, where vendor lock-in mitigation techniques are well-established.

Expanding upon the conceptual model, and maintaining its structural outline, the mitigation techniques are categorized into two groups: contractual strategies and relational strategies. The former is designed to prevent or alleviate the risks of vendor lock-in at the outset of the contractual relationship. The latter are employed to manage and mitigate the risks that are inherent in ongoing supplier-client relationships.

This section provides a detailed examination of both sets of strategies, offering insights into their practical application and evaluating their effectiveness in mitigating the risks associated with vendor lock-in. By distinguishing between the preventative measures taken during the contract negotiation and drafting stages, and the adaptive strategies applied during the lifecycle of the contract, this analysis illuminates the dynamic approaches organizations can undertake to maintain robust and flexible equitable supplier-client relationships.

5.1. Vendor Lock-In Risks

Because of the CSS contract's complex nature, ProRail is subject to every risk mentioned in the vendor lock-in framework outlined in the Background chapter; asset specificity, limited pool of suppliers and client's expertise. The ERTMS requires dedicated investments, such as specialized contracts and collaboration teams, indicative of asset specificity. The novelty of ERTMS implementation further elevates asset specificity in conjunction with each nation's distinct requirements. Furthermore, the limited pool of qualified suppliers from program complexity may place ProRail in a weaker bargaining position. However, despite the limited number of potential vendors, the program's significant scale and impact warranted a competitive tender process. This competition mitigates the potential disadvantage in bargaining power associated with program complexity.

Although Thales owns the intellectual property created for the CSS program, ProRail has implemented "Open Engineering" as a partial mitigation technique. This program seeks to promote competition and eventually lessen reliance on Thales by allowing independent engineering firms to take on specific installation responsibilities. Another risk factor was the client's expertise. At first, the Asset Management division was unfamiliar with these collaborative work models. Interviews indicated early challenges in adjusting to this new method; however, given the program's complexity, its use was recognized as necessary. Hiring IT experts reduced the chance of forgetting essential contract terms, like those about termination and intellectual property rights.

5.2. Contractual Strategies

This section delves into various contractual strategies that can be employed to suppress the harmful risks of vendor lock-in. These strategies include 1) flexible contracting, 2) mutual hostaging, and 3) dual sourcing (Bahli & Rivard, 2003).

The presence of the contractual mitigation strategies outlined in the conceptual framework is evident in ProRail's approach. ProRail made a notable choice when they decided against dual sourcing, prioritizing the quality of their products over the potential advantages of using multiple suppliers. This decision was made due to the program's inherent complexity and concerns about maintaining strict quality standards. ProRail recognized the potential benefits of a multi-sourced approach but concluded that its internal resources could not handle the challenges of managing several suppliers while maintaining product quality. This choice necessitated an even greater focus on the remaining vendor lock-in mitigation strategies, particularly mutual hostaging and flexible contracting.

5.2.1. Flexible Contracting

Flexible contracting is a critical tactic in reducing vendor lock-in. This strategy involves adding clauses that permit dynamic modifications to outsourcing agreements. These clauses may include variable pricing plans, term renegotiation, flexible termination policies, and the option to shorten the contract's duration. The fundamental idea behind flexible contracts is to recognize that changes to the contractual agreement may be necessary due to the inherent unpredictability of external factors. The client and the supplier can adjust to changing circumstances while guaranteeing mutual protection by leaving some aspects up for renegotiation (Harris et al., 1998).

In an example outlined by (Aubert et al., 2006) the client used a "sequential contracting" strategy to protect against lock-in. The client connected the contract duration to verifiable performance milestones by separating the program into phases. This method ensured program completion while permitting termination if needed. Additionally, the contract included a substantial underperformance penalty equal to five times the total contract value to reduce the risk of service degradation. This fine functioned as insurance, lessening the financial impact of any service lapses and serving as a strong incentive for the supplier to maintain high effort levels. The client relied on a thorough inventory of components and interactions to establish precise evaluation methods and secure guaranteed rates to address cost escalation. Therefore, using a flexible contracting approach, the possible losses brought on by lock-in, service degradation, and cost escalation were significantly decreased.

ProRail's contract strategy emphasizes two key pillars – collaboration and flexibility – designed to navigate the program's complexity and suppress vendor lock-in risks. Flexible contracting allows ProRail to modify the terms of the contract so that it remains appealing to Thales for the duration of the agreement. Although the current degree of flexibility seems to go beyond what the Asset Management department has used in the past, it remains to be seen if this will effectively keep Thales involved in the later stages.

5.2.2. Mutual Hostaging

Mutual hostaging emerges as a potent tactic to reduce the risks associated with vendor lock-in by promoting a relationship based on mutual success and interdependence. This strategy moves away from traditional models towards cooperative partnerships. It is accomplished by establishing mutual exposure to assets, thereby linking the enterprise's success to the prosperity of both the supplier and the client (Koss et al., 1997).

Mutual hostaging is based on the partial redistribution of investment costs. The client may incur expenses in educating the supplier's staff about their specific systems, procedures, and processes. The supplier may feel ‘hostage’ due to the investment in their knowledge and skill

set, which now holds significant value within the client relationship, discouraging them from leaving. On the other hand, the supplier may invest in specialized human or physical resources to meet the client's specific requirements. This mutual investment fosters a level of commitment from both parties, promoting a healthy and value-driven partnership. Moreover, mutual hostaging offers benefits beyond avoiding lock-in and fostering a collaborative spirit between the supplier and the client through this strategic alliance. Both parties are incentivized to cooperate to achieve mutually beneficial results. Suppliers are more likely to prioritize the needs of their clients and work towards ongoing improvement if they invest in client-specific expertise. In turn, the client benefits from a highly competent and engaged supplier who has a stake in the success of the collaboration. This cooperative strategy encourages candid dialogue, creative problem-solving, and innovation, which can result in a more effective and profitable outsourcing arrangement.

For instance, a client that outsources the management of their IT infrastructure may choose to fund the supplier's personnel training on their unique healthcare data security procedures through mutual hostaging. In response, the supplier may invest in data storage options and dedicated servers designed to meet the client's compliance needs. Both parties rely on each other's success and expertise due to this mutual investment. The supplier is less likely to act opportunistically because they know that their investment in client-specific knowledge would be lost in the event of a partnership breakdown. On the other hand, the client benefits from having a highly knowledgeable and involved partner who has a stake in maintaining the effectiveness and security of their IT infrastructure.

Interviews conducted with both ProRail and Thales personnel provide compelling evidence supporting the effectiveness of the mutual hostaging strategy. Thales personnel highlighted numerous mutual benefits arising from this collaborative approach, emphasizing that it has significantly improved their operational efficiency and the quality of their deliverables. Thales team members expressed that this partnership has not only streamlined communication and program coordination but has also fostered a culture of shared responsibility and mutual respect. They noted specific instances where collaborative problem-solving led to innovative solutions that would have been difficult to achieve independently.

On the other hand, ProRail's internal interviews shed light on their strategic focus on cultivating a mutually advantageous relationship with Thales. ProRail employees consistently pointed out that this approach has been instrumental in suppressing opportunistic behaviour, ensuring that both parties remain committed to the program’s long-term success rather than short-term gains. They cited examples of how this strategy has mitigated vendor lock-in risks, allowing ProRail to maintain flexibility and leverage in their contractual agreements.

5.2.3. Dual Sourcing

Another important mitigation technique is dual sourcing. This involves hiring multiple vendors to provide specific services, guaranteeing high performance, affordability, and satisfactory service quality (Bahli & Rivard, 2003). The purpose of dual sourcing is to maintain high levels of performance and quality from each vendor by threatening to lose business to alternative suppliers. This competitive environment reduces the risks associated with vendor lock-in and ensures that a single supplier does not become complacent.

For instance, a large grocery chain, Publix, opted to work with three different suppliers instead of relying on a single supplier. This strategy made the market more competitive and ensured

supply chain redundancy. The presence of two more suppliers familiar with Publix's operations would reduce the impact of any disruption, even if one supplier were to fail, preventing lock-in. Additionally, the client gains valuable performance insights from supplier interactions, which promote responsible decision-making and accountability within the supplier network (Aubert et al., 2003). ProRail decided against dual sourcing due to the program's complexity and the need to maintain high-quality standards. However, this necessitated a strong emphasis on the remaining mitigation strategies. ProRail's decision to focus on collaboration and flexibility during the contract phase appears promising. The real test, though, will come during the execution stage, when ProRail's capacity to use alliance and dynamic capabilities will be essential.

5.3. Relational Strategies

Relational mitigation strategies are critical during the execution stage of the contract to manage and mitigate the risks inherent in ongoing supplier relationships. In this context, three areas are highlighted: 1) Dynamic capabilities, 2) absorptive capacity, and 3) alliance capabilities (Maley et al., 2015).

5.3.1. Dynamic Capabilities

Dynamic capabilities are essential for ProRail to manage unforeseen opportunities and challenges that may arise during the execution of the ERTMS program. In today's dynamic business environment, a static set of firm capabilities is insufficient (Ambrosini & Bowman, 2009). Firms must develop dynamic capabilities, adapting, renewing, and modifying their capabilities in response to changing circumstances (Hätönen & Eriksson, 2009). Evidence indicates that ProRail is actively increasing its capacity to absorb information. According to interviews, they monitor market trends, promote knowledge exchange within the company, and work with academic institutions. By taking a proactive stance, they can keep up with technological developments and possibly spot opportunities to add new features or improve the efficiency of the ERTMS system.

Furthermore, dynamic capabilities enable organizations to proactively identify and address potential sources of lock-in, thereby minimizing their dependence on a single vendor and enhancing their ability to explore alternative solutions (Cepeda & Vera, 2007). ProRail appears to be implementing a "learning by doing" strategy, as evidenced by creating a dedicated collaboration team and employing an outside party to handle collaboration. This approach facilitates ongoing innovation and improvement within the operational framework of the contract. By continuously refining internal processes, integrating new technologies, and upskilling personnel, organizations can maintain alignment with evolving market demands and reduce their reliance on specific vendors (Wang & Ahmed, 2007). As a result, ProRail can build internal expertise in working with outside partners like Thales and gain invaluable experience managing complicated programs.

During the operational stage of a contract, dynamic capabilities also enable organizations to foster strategic alliances and cooperative relationships with vendors. Organizations can foster mutual understanding and trust with vendors by promoting transparency, creating clear expectations, and encouraging open communication channels. This cooperative strategy fosters a win-win mindset and reduces the possibility of opportunistic behaviour, strengthening and extending the vendor-client relationship.

Although the current contract has more flexibility than the Asset Management department has historically used, it is unclear how well ProRail will be able to modify the terms of the program or the contract if needed. Their ability to handle unforeseen technical obstacles or changes in regulatory requirements that may arise during execution will be the real litmus test of their strategic flexibility. A fruitful cooperative relationship with Thales will require proactive adaptation to such obstacles. By enhancing its dynamic capabilities, ProRail can ensure that it remains responsive to changing market conditions and client needs, ultimately mitigating the risks of vendor lock-in and ensuring the successful implementation of the ERTMS program.

5.3.2. Absorptive Capacity

Wang & Ahmed (2007) propose absorptive capacity as the primary dynamic capability, prompting further elaboration on its significance and implications.

Absorptive capacity empowers organizations to seamlessly integrate newfound knowledge with their existing capabilities, enhancing their ability to navigate the intricacies of outsourcing relationships (Cepeda & Vera, 2007). Moreover, absorbing new information is crucial for adjusting to new practices. When a supplier and client create a collaborative environment, employees must adapt to new procedures that may vary from the well-known ones traditionally in place (Cepeda-Carrion et al., 2012).

ProRail demonstrates a strong commitment to enhancing its absorptive capacity. By actively engaging in continuous learning and knowledge exchange, ProRail ensures that it remains at the forefront of technological and procedural advancements. For instance, ProRail promotes knowledge sharing within the company and collaborates with academic institutions to stay updated on the latest industry trends and innovations. This proactive stance enables ProRail to identify and integrate new practices and technologies, thereby improving the efficiency and effectiveness of the ERTMS program.

Absorptive capacity has a dual role: it enables organizations to effectively manage knowledge while fostering innovation and capability development, thereby enabling organizations to derive maximum value from their collaboration. Additionally, these capabilities encompass specialized competencies in managing suppliers, referred to as ‘alliance capabilities’ (Wang & Rajagopalan, 2014).

5.3.3. Alliance Capabilities

Possession of alliance capabilities gives a client a competitive advantage because it allows it to effectively manage vendors, including proper supplier selection and trust-based relationships (Ireland et al., 2002). Strategic supplier selection is a crucial component of alliance capabilities and is a complex process that goes beyond traditional evaluations of technical expertise and cost. Clients with alliance capabilities can look past performance measures and assess a vendor's flexibility, teamwork ethic, and overall goals. This ability makes it easier to build long-lasting alliances and creates the foundation for successful collaboration inside the program.

Repeating with the same supplier can strengthen the alliance by promoting better coordination and joint value creation. On the other hand, frequent interactions may cause the supplier to prioritize personal gain over creating shared value, leading to an unequal distribution of benefits that harms the alliance's long-term viability (Kumar, 2010).

Furthermore, Maley et al. (2015) states that alliance capabilities can be divided into two levels: 1) dyad-specific alliance capabilities, representing the relational competencies of the collaboration; and 2) individual alliance capabilities, focusing on a client's capacity to initiate, manage, and conclude contracts with suppliers.

ProRail's commitment to fostering a collaborative environment extends beyond establishing a dedicated team and financial incentives. Engaging a dedicated collaboration company further underscores their proactive approach to developing strong alliance capabilities. This external expertise facilitates communication, manages expectations, and proactively addresses potential roadblocks, fostering a more effective and trusting partnership with Thales.

ProRail has an exceptional chance to work with Thales in a cooperative partnership through the ERTMS program. Data points to a change in ProRail's strategy, moving away from conventional command-and-control frameworks towards a cooperative problem-solving framework. This is demonstrated by the creation of a specialized team for collaboration, a feature that Thales employees were not previously exposed to, according to the interviews conducted with Thales employees. This shift in emphasis towards teamwork in resolving program issues represents a possible paradigm shift within ProRail.

"Even though I was based in South Africa, I worked on international programs, and I've never seen this type of collaboration in my 15 years of experience." (Contract Manager, Thales)

While detailed data on specific relationship management tactics employed by ProRail is limited, the available evidence points towards efforts to build trust and establish a mutually beneficial partnership with Thales. Including collaboration and innovation funding within the contract can be interpreted as a strategic move towards a "win-win" scenario. Sustaining a robust and long-term alliance necessitates consistent communication and a commitment to promptly addressing any concerns raised by Thales.

One critical approach to aligning objectives and incentives for both parties involves the collaboration and innovation budget incorporated into the contract. ProRail aims to incentivize Thales' dedication to the program's success by rewarding outstanding work and focusing on shared benefits. However, the long-term effectiveness of this strategy hinges on ProRail's consistent commitment to collaborative practices and ensuring an equitable distribution of benefits throughout the entire program lifecycle.

ProRail's commitment to fostering a collaborative environment extends beyond establishing a dedicated team and financial incentives. Engaging a dedicated collaboration company further underscores their proactive approach to developing strong alliance capabilities. This external expertise facilitates communication, manages expectations, and proactively addresses potential roadblocks, fostering a more effective and trusting partnership with Thales. By focusing on dynamic capabilities and absorptive capacity, ProRail can enhance its strategic flexibility and ensure a productive and successful partnership throughout the ERTMS program's lifecycle.

6. Reflection

The case study of ProRail underscores the critical importance of proactive mitigation strategies to address vendor lock-in from the outset. This awareness may not be uniformly prevalent across the entire infrastructure sector, especially in areas undergoing rapid digitalization. Digitalization in infrastructure programs introduces additional layers of complexity, where evolving technological landscapes exacerbate the challenges of mitigating vendor lock-in. The implications of vendor lock-in extend beyond the rail sector, necessitating further research to develop comprehensive strategies for managing these risks across diverse infrastructure programs. This aligns with the growing trend of exploring programmatic collaborations within the infrastructure sector.

ProRail's strategic decisions during the ERTMS program, particularly concerning the CSS contract, provide a practical framework for understanding how to mitigate vendor lock-in. These decisions are analysed through the lens of vendor lock-in mitigation strategies from the literature, providing a comparative perspective. ProRail made a significant decision against dual sourcing, prioritizing the quality of its products over the potential advantages of using multiple suppliers. This choice was driven by the program's inherent complexity and concerns about maintaining stringent quality standards. Although ProRail recognized the potential benefits of a multi-sourced approach, it concluded that its internal resources could not handle the challenges of managing several suppliers while maintaining product quality. This decision highlights the need for a strong emphasis on other mitigation strategies such as mutual hostaging and flexible contracting.

Flexible contracting involves clauses that permit dynamic modifications to outsourcing agreements, including variable pricing plans, term renegotiation, flexible termination policies, and the option to shorten the contract's duration. The idea is to recognize the unpredictability of external factors and allow both parties to adjust accordingly. ProRail's strategy of flexible contracting is reflected in its ability to modify terms to keep the contract appealing to Thales. This approach aligns with literature findings that suggest flexible contracts can significantly reduce the adverse effects of vendor lock-in.

Mutual hostaging is exemplified by ProRail's introduction of a dedicated collaboration and innovation budget, incentivizing Thales to remain committed to delivering high-quality work. Mutual hostaging involves both parties making investments that tie their success to the collaboration's success. This strategy fosters a relationship based on mutual success and interdependence, reducing the risks associated with vendor lock-in.

Given the decision to forgo dual sourcing, ProRail had to emphasize remaining mitigation strategies during the operational phase. Cooperation and adaptability are critical during this phase, and ProRail's capacity to leverage dynamic capabilities and alliance capabilities will be essential. Dynamic capabilities enable organizations to proactively identify and address potential sources of lock-in, thereby minimizing dependence on a single vendor and enhancing the ability to explore alternative solutions. ProRail's proactive stance is evident in their efforts to monitor market trends, promote knowledge exchange within the company, and collaborate with academic institutions. This approach aligns with the literature, which emphasizes the importance of dynamic capabilities in maintaining operational flexibility and efficiency.

Absorptive capacity is crucial for integrating new knowledge and practices, enabling organizations to navigate the intricacies of outsourcing relationships effectively. ProRail's commitment to learning and adapting, as seen in its creation of a dedicated collaboration team and engagement with external parties for collaboration management, reflects a strong absorptive capacity.

Possessing robust alliance capabilities allows clients to manage vendors effectively, ensuring proper supplier selection and fostering trust-based relationships. ProRail's shift towards a cooperative problem-solving framework and the inclusion of collaboration and innovation funding within the contract illustrate their efforts to build a mutually beneficial partnership with Thales. This strategy is in line with literature emphasizing the importance of alliance capabilities in maintaining long-term, successful vendor relationships.

The comparison between ProRail's mitigation strategies and those identified in the literature reveals several key insights. Both ProRail's practices and the literature highlight the importance of flexibility and the ability to adapt contractual and relational strategies in response to changing circumstances. This flexibility helps manage the unpredictability inherent in complex infrastructure programs. ProRail's approach to mutual hostaging aligns well with literature findings that suggest mutual investments by both client and supplier can foster a more cooperative and less opportunistic relationship, thereby mitigating vendor lock-in risks. Additionally, ProRail's emphasis on developing dynamic and alliance capabilities is supported by the literature, which underscores the necessity of these capabilities in managing ongoing vendor relationships and adapting to new challenges and opportunities.

The literature generally supports the idea of dual sourcing to reduce the risks of vendor lock-in. However, ProRail's context-specific decision against dual sourcing, due to the program's complexity and quality concerns, illustrates the need for tailored strategies based on specific program requirements.

The case study of ProRail demonstrates the effectiveness of well-defined contractual and relational mitigation strategies in managing vendor lock-in risks in complex infrastructure programs. By adopting flexible contracting, fostering mutual hostaging, and developing dynamic and alliance capabilities, ProRail has navigated the challenges of vendor lock-in in the ERTMS program effectively. Future research should aim to expand on these findings by exploring multiple case studies across diverse contexts and contract stages, particularly towards the end of contracts. Additionally, investigating the interplay between vendor lock-in and other risks associated with infrastructure program contracts would provide a more comprehensive understanding of the risk landscape. This broader perspective will help develop more effective risk management strategies, ensuring the successful delivery of essential infrastructure programs. By continually refining and implementing these strategies, stakeholders can mitigate the negative impacts of vendor lock-in, foster healthy vendor-client relationships, and achieve better outcomes in complex infrastructure programs.

6.1. Limitations

The ProRail case study, conducted during the initial phase of the contract, offers valuable insights into the early stages of vendor lock-in. However, the full impact of this phenomenon may only become apparent later in the contract lifecycle. To gain a more comprehensive understanding, future research should include case studies conducted towards the end of contracts. This approach would provide a fuller picture of how vendor lock-in evolves and its

long-term effects on program outcomes. Relying on a single case study limits the generalizability of the findings. Conducting multiple case studies across various program contexts, especially towards the end of contracts, would offer a richer comparative analysis and deeper insights into the manifestations of vendor lock-in. Such comparative studies would enhance the understanding of how different contexts and contract structures influence the extent and impact of vendor lock-in.

While this research primarily focuses on vendor lock-in, the broader outsourcing literature highlights additional risks associated with infrastructure program contracts. These include contractual modifications, transition expenses, disputes, and litigation. Future research exploring the interplay between vendor lock-in, and these additional risks would provide a more holistic understanding of the complex risk landscape. Furthermore, assessing the applicability of existing mitigation strategies to these various risks could equip stakeholders with more comprehensive risk management tools.

7. Conclusion & Recommendations

This chapter synthesizes the findings of the research, addressing the critical issue of mitigating vendor lock-in within infrastructure programs governed by framework agreements, with a particular focus on ProRail's CSS contract as part of the ERTMS program. The analysis, guided by the primary research question, "How to mitigate vendor lock-in situations within infrastructure programs covered by framework agreements?" is structured around three sub-research questions. These questions provide comprehensive insights into the characteristics, challenges, and strategies for managing vendor lock-in, culminating in actionable recommendations for ProRail and similar organizations.

7.1. Conclusion

This research has addressed the critical issue of mitigating vendor lock-in situations within infrastructure programs governed by framework agreements, focusing specifically on ProRail's CSS contract as part of the ERTMS program. The primary research question, "How to mitigate vendor lock-in situations within infrastructure programs covered by framework agreements?" has been explored through three sub-research questions, yielding comprehensive insights into the characteristics, challenges, and strategies for managing vendor lock-in.

The first sub-research question examined the characteristics and challenges of vendor lock-in within large infrastructure programs. Vendor lock-in arises from the interactions between a client and a supplier of a product or service. Understood through two components: contractual performance and relational dynamics. The findings revealed that the inherent complexity of infrastructure programs, exacerbated by digitalization, leads to significant entry barriers and high switching costs. These factors bind clients to their suppliers, increasing the risk of vendor lock-in. ProRail's experience illustrates how these complexities necessitate a revaluation of traditional contract types and the adoption of more flexible and collaborative frameworks to manage long-term supplier relationships effectively.

The second sub-research question investigated the lessons from IT and other industries regarding vendor lock-in prevention. Strategies from the IT sector, such as flexible contracting, mutual hostaging, and dual sourcing, were identified as effective mitigation techniques. These strategies emphasize the need for adaptability in contracts, shared investments between clients and suppliers, and maintaining a competitive supplier environment. Comparing these strategies to ProRail's practices revealed similarities in the emphasis on flexibility and collaboration, although the infrastructure sector's unique complexities require tailored approaches.

The third sub-research question focused on how ProRail can enhance its strategies within the CSS contract to mitigate vendor lock-in risks. ProRail's proactive measures, including the involvement of IT-specialized managers and the implementation of "Open Engineering," highlight their commitment to reducing reliance on a single supplier. However, the decision against dual sourcing due to the program's complexity underscores the necessity for robust alternative strategies. ProRail's emphasis on collaboration and flexibility through mutual hostaging and dynamic contracting has proven effective in maintaining the contract's attractiveness and fostering a cooperative relationship with Thales.

In response to the overarching research question, the study concludes that mitigating vendor lock-in in infrastructure programs requires active risk management throughout all contract phases. ProRail's case study demonstrates that the decision-making process and proactive

management significantly influence the degree of vendor lock-in risks. The strategies of collaboration, mutual hostaging, and flexible contracting adopted by ProRail have shown to be effective in addressing these risks.

7.2. Recommendations

While the current satisfaction levels between ProRail and Thales are high, the potential for vendor lock-in as the contract progresses necessitates continued attention. Proactive management is essential to preserving a mutually beneficial relationship. Emphasizing alliance-building and dynamic capabilities, rather than solely focusing on contractual specifics, can help mitigate the adverse effects of vendor lock-in.

Additionally, the research literature frequently cites outsourcing literature where open-source technology adoption is also mentioned as a potential solution to mitigate vendor lock-in within the IT infrastructure. Although the extensive use of hardware in the ERTMS program limited the immediate applicability of open-source solutions, particularly in the context of the CSS contract, it remains a viable strategy for addressing vendor lock-in risks in software-intensive aspects. This potential solution was also highlighted during discussions with the expert panel, suggesting that a deeper investigation into open-source technologies, especially for software aspects, is advisable.

Furthermore, the research literature highlights other risks associated with infrastructure program contracts, such as expensive contractual amendments and unforeseen management costs. Addressing these additional risk factors can contribute to developing a comprehensive risk management framework for future infrastructure programs.

By fostering a culture of continual improvement, ProRail can navigate the complexities of vendor lock-in and ensure the sustained success of its infrastructure programs. Leveraging insights from diverse industries and scholarly literature will inform strategic decisions, enhancing ProRail's approach to managing vendor relationships. Through ongoing evaluation, adaptation, and innovation, ProRail can strengthen its resilience against vendor lock-in and other associated risks, ultimately contributing to the successful delivery of critical infrastructure programs.

This research underscores the importance of proactive risk management, flexibility, and collaboration in mitigating vendor lock-in in complex infrastructure programs. The lessons drawn from ProRail's case study and the broader literature provide a valuable framework for other organizations facing similar challenges, paving the way for more resilient and successful infrastructure programs in the future.

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Appendix I

General Interview List

This interview questions list aims to be broadly applicable while still capturing deep insights into key topics relevant to vendor lock-in.

1. Can you provide an overview of your role within your organization and your involvement in major contracts or projects?
2. How does your role contribute to the formulation and execution of contract strategies?
3. What key factors are essential for identifying situations of vendor lock-in in your contracts?
4. What measures do you implement during procurement strategy and contract formation to avoid vendor lock-in?
5. How are these measures adjusted during the ongoing phases of the contract?
6. How would you describe the relationships between your organization and key suppliers or partners within ongoing contracts?
7. Are there specific behavioural aspects or communication styles that play a significant role in these relationships?
8. What is the impact of a programmatic approach in your contracts compared to conventional projects?
9. How does this approach contribute to or prevent vendor lock-in situations?
10. From your perspective, what values and factors are crucial for a successful collaboration with suppliers or partners?
11. Are there insights from previous collaborations that have positively influenced the dynamics of current contracts?
12. Can you describe some unexpected situations that have occurred during earlier phases of contract management and how they influenced decision-making?

Appendix II

Expert Panel Validation

26-03-2024, 11:00 a.m., ProRail Office Utrecht:

ProRail:

- Purchasing strategist train safety system, involved in designing the CSS contract.
- Contract manager during the procurement stage CSS.

Programme Board (PD):

- Programme Direction ERTMS (PD), involved in designing the CSS contract strategy.

Thales:

- Deputy General Program Manager was involved during the operation phase of the CSS.

University of Twente:

- PhD Candidate, Construction Management & Engineering Department

Introduced Propositions:

- "ProRail intentionally engages in a Vendor Lock-In situation with Thales."
- "Mutual Tolerance suppresses the negative effects of a single supplier vendor lock-in."
- "Conflicts are effectively prevented through informal collaboration."
- "The involvement of a collaboration management partner represents an effective method of informal collaboration."
- "A good contract is robust enough to be left untouched."
- "Vendor Lock-In can only be prevented through technology-independent solutions."

Separate Expert Panel session: Director Marketing & Sales Thales, 21-03-2024, 10:00 a.m., Thales Office Utrecht