Electrifying the Mining Industry

A Case Study on How Suppliers Use Business Model Innovation to Drive Battery Electric Vehicle Adoption

Master's thesis in Quality and Operations Management

Axel Helgesson & Jakob Nilsson

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF INNOVATION AND R&D MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
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AXEL HELGESSON
JAKOB NILSSON

Supervisor: Linus Thomson, Technology Management and Economics
Examiner: Ksenia Onufrei, Technology Management and Economics

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Department of Technology Management and Economics
Division of Innovation and R&D Management
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 10 00

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Abstract

With increasing pressure on the mining industry to cut emissions from diesel-powered operations, the adoption of Battery Electric Vehicle (BEV) is becoming a priority. The underground mining environment does however pose a uniquely challenging adoption context. This study examines the adoption barriers of BEV in underground mining and how equipment suppliers are addressing these through Business Model Innovation (BMI). This study adopts a qualitative case study design where data were mainly collected through semi-structured interviews with Volvo Group employees and a large Swedish mining company.

The findings show that the barriers to BEV adoption in underground mining are not independent, but compound in ways that constrain what customers can adopt and what suppliers can credibly offer. The productivity imperative of mining operations is an amplifying condition where it intensifies all of the identified barriers. The response from equipment suppliers has been that the primary form of BMI enacted is through servitization in the form of bundled service contracts and as-a-service models. Servitization can however be self-limiting, as the risk premiums required to offer these advanced service arrangements can simultaneously increase the economic barrier they were designed to overcome. The study also finds that closing organizational gaps in pricing competence, cross-unit coordination, and sales process adaptation are preconditions for servitization to function as intended. This positions value delivery as an often overlooked dimension of BMI in capital-intensive industrial contexts.

Keywords: Business Model Innovation, Servitization, Battery Electric Vehicles, Total Cost of Ownership, Underground Mining, Adoption Barriers, Risk Transfer

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List of Acronyms

BEV	*Battery Electric Vehicle*: A vehicle that runs entirely on electric power, storing the energy in battery packs. In the context of this report, BEV is specifically referred to as heavy duty haulage trucks used in mining operations.
BM	*Business Model*: Determines how a company creates, delivers and captures value.
BMI	*Business Model Innovation*: The process by which a company reconfigures its business models, often including changes to the product, service, and revenue model.
CAPEX	*Capital Expenditure*: Upfront investments that are recorded on the balance sheet.
EaaS	*Equipment-as-a-Service*: A business model where the customer pays for the usage of equipment rather than owning the asset.
ICE	*Internal Combustion Engine*: A vehicle that has a traditional combustion engine that uses fossil fuels, such as diesel or gasoline for power.
OPEX	*Operational Expenditure*: Ongoing and often recurring costs associated with operating equipment or a business, such as maintenance, energy, and fuel.
TCO	*Total Cost of Ownership*: The total cost that is associated with owning and operating specific equipment over its lifetime.

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1 Introduction

1.1 Background

The demand for crucial earth metals is projected to multiply over the coming years, catalyzed by the expansion of new energy technologies that require substantial amounts of metals and minerals (IEA, 2025). By 2040, the demand is projected to double, and by 2050, if net-zero goals are to be met, the demand would be six times that of 2020 (IEA, 2021). Mining is the primary means to supply this demand (Worlanyo & Jiangfeng, 2021). Historically, mining has been a key activity for the development of several countries economically and continues to help countries attract foreign investments, speed up the development of infrastructure, and create new jobs (Worlanyo & Jiangfeng, 2021). For Sweden specifically, the mining industry delivers significant value. It is currently a major employer, both through direct roles within mining companies and through indirect employment in the vast network of suppliers. The sector also contributes to 3% of the Swedish GDP and significant tax revenue (Svemin, n.d.). Beyond economic value, domestic mining strengthens self-reliance on supply of metals and minerals, thereby reducing the dependence on imports (Svemin, n.d.).

While mining has had positive economic effects, it has also contributed substantially to environmental degradation. This ranges from local effects such as health risks at and around the site, to remote contamination of soil and water in other geological areas, as well as the global effects from increased greenhouse gas emissions (da Silva-Rêgo et al., 2022). The Swedish government-initiated platform, Fossilfritt Sverige (2022), identifies the mining and mineral industry as responsible for a significant portion of the total emissions in Sweden, generating about 7% of the country's total CO2 emissions. Diesel consumption accounts for nearly half of the total emissions, with the usage of diesel-powered trucks being the primary driver (Fuentes et al., 2026). Therefore, reducing usage of fossil fuels in the mining operation is one driver for the adoption of clean technology, such as Battery Electric Vehicles (BEV) (Fossilfritt Sverige, 2022). While there are other alternatives for clean technologies, for example LNG fuel, introduction of BEV can achieve the highest drop in emissions (Fuentes et al., 2026). Another benefit of the BEV transition is the improvement of working conditions caused by lower emissions in the mine, resulting in improved air quality and the possibility of lower ventilation demands, and subsequently lower costs (Grishin et al., 2020).

1.2 Problem Identification and Thesis Aim

Despite the benefits, the transition to BEV can be cumbersome due to several adoption barriers. Sugihara et al. (2023) have identified three main categories of barriers to the electrification of heavy-duty trucks: economic barriers such as high purchase cost and unreliable residual value; technological barriers including charging possibilities, payload capacity, and reliability of the truck; and social barriers such as cultural resistance and lack of education. While these categories provide a useful starting point, Sugihara et al.'s study focused on fleets operating in California on open road transportation, which differ considerably from the mining environment in Sweden. Mining operations are characterized by extreme uptime dependency, where unplanned downtime directly halts ore production. The underground environments impose unique constraints on charging infrastructure and ventilation (Assimi et al., 2023; Jacobs & Hodkiewicz, 2014). These characteristics suggest that the barriers to BEV adoption in mining extend beyond, or manifest differently from, those identified in general truck electrification research. Despite prior insights into the barriers of electrification of road haulage trucks (Sugihara et al., 2023; Peachey, 2025), the characteristics of BEV in the mining industry remain underexplored.

Addressing barriers with the adoption of BEV is a key factor in enabling the transition to electrification of the mining industry. Equipment suppliers play a central role in this, for several reasons. They possess unique knowledge about technical aspects such as battery technology and charging possibilities. Capitalizing on this means that the mining companies can focus on their core activities (Kowalkowski et al., 2015). Suppliers also maintain established relationships with critical stakeholders in the battery and electricity industry, which can be useful to combat range and charging constraints. Furthermore, the barriers mentioned above contain operational risks (e.g. uptime) which may be excessive for a mining company to assume independently. However, suppliers can help with risk mitigation and redistribute risk across several customers (Kowalkowski et al., 2017). Suppliers can also offer different commercial arrangements that might have different implications from a financial perspective, thereby altering the Total Cost of Ownership (TCO) for BEV acquisition, which could reduce financial barriers. Considering the above, this positions the equipment supplier as a key actor in facilitating the BEV transition in the mining industry. Beyond their internal capabilities to address the barriers, equipment suppliers have their own incentives to accelerate the shift. Suppliers face strong financial and regulatory pressure to electrify their product offerings. In the EU, there are laws and regulations pushing manufacturers to produce carbon-free trucks (IER, 2024).

While suppliers are well-positioned to address these barriers, the value offered by acquiring BEV is insufficient to convince buyers to accelerate electrification. The value problem is further highlighted by Macdonald et al. (2016), who argue that simply using a product is not the sole quality assessor of an offering, but also the quality of surrounding processes and resources. For mining companies, that would mean that the truck's technical potential alone cannot be the sole value constituent.

Therefore, a broader understanding of what constitutes value for the customer is needed. Teece (2010) argues that technological potential is not automatically translated to economic success. Therefore, overcoming the adoption barriers requires suppliers to move beyond transactional product sales (Cannon & Perreault, 1999) and reconfigure how they create, deliver, and capture value. The process through which an organization creates and captures new value is called business model innovation (BMI) (Sjödin et al., 2020). It is increasingly recognized as essential for the successful commercialization of new technologies in industrial contexts (Adrodegari & Saccani, 2017; Chesbrough, 2010).

Although BMI is widely accepted as an essential part of new technology adoption (Teece, 2010; Sjödin et al., 2020), the existing literature regarding this phenomenon is not sufficient for understanding how suppliers configure these BMs when customers are faced with the previously mentioned adoption barriers in a capital-intensive context. Studying how BMI is currently performed by equipment suppliers to overcome these barriers in the mining context would enable the creation of new value propositions that are better targeted at customer needs and subsequently allow more widespread adoption of BEV in the mining industry.

1.3 Research Questions

The push towards more sustainable mining practices requires new technologies to be adopted. One of these potential technologies is BEV. While prior research has examined electrification barriers in mining, existing studies have not specifically addressed BEV in underground applications. These environments create operational constraints and productivity demands that result in a specifically challenging adoption environment. Where barriers have been identified, the commercial and BMI implications for equipment suppliers remain largely underexamined. RQ1 therefore serves a dual purpose by grounding the study in a context that existing literature has not fully addressed, and providing the necessary precondition for analyzing the BMI responses examined in RQ2. This leads to the following research questions:

RQ1 *What adoption barriers of BEV exist in the mining industry?*
RQ2 *How does BMI by equipment suppliers help overcome barriers to adoption of BEV in the mining industry?*

1.4 Scope

The research area can be considered broad and has different implications for different settings. Therefore, to focus the research effort the following limitations will be made.

This report is limited to the Swedish mining industry. The main reasons for this are the access to stakeholders and availability of relevant data through contacts at Volvo Trucks (VT). Therefore, the findings may be specific to certain regulatory, market, and operational conditions that are particular to Sweden, e.g., labor cost, energy cost, infrastructure. Consequently, our findings cannot be directly generalized to all global mining markets without modification.

Within the value chain of a Swedish mine, this thesis will focus on the haulage of raw material within the mine. This includes transportation from the extraction point to the surface of the on-site processing facility, which is characterized by heavy load and steep inclines.

2 Theoretical Background

This chapter provides a theoretical context for addressing the two research questions. Existing literature on adoption barriers is presented and provides a theoretical background for the study. The following sections also introduce BMI and servitization as the theoretical lenses through which suppliers respond to the barriers identified.

2.1 Barriers to Electrified Mining Operations

Adoption of new technology can provide several benefits for an organization, including increased productivity, reduced cost, improved quality, and enhanced competitiveness of a firm (Noori, 1987). However, adoption of new technologies is rarely straightforward, and innovations often face significant barriers that slow diffusion (Rogers, 1983). Teece (2010) further argues that technological innovation does not automatically translate into commercial success, since adoption depends on factors beyond the technology itself. Hall & Khan (2003) argue that what in many cases determines adoption is the relation between the cost of adoption and the perceived benefits. These benefits are not limited to economic gains, but may also include reputational gains from being perceived as innovative and forward-thinking (Hall & Khan, 2003).

The Technology-Organization-Environment (TOE) framework, as presented by Baker (2012), states that a firm's adoption decisions are influenced by three elements. The technological element evaluates the relative improvement the available technology offers and its compatibility with what already exists. Rogers (1983) argues that compatibility and integration challenges arise for new technologies that must be incorporated with the existing systems, which increases the complexity of adoption. The organizational element considers internal conditions such as investment capacity, managerial support and attitudes toward change within the organization (Baker, 2012). Employee resistance may emerge in the form of replacement concerns or the need for new skills to operate the new technology, creating additional barriers (Tajuddin, 2025). The environmental element considers external conditions regarding what prevailing regulations and incentive structures exist, as well as the characteristics of the industry (Baker, 2012).

Furthermore, adoption of new technology requires substantial investment, not only in the equipment itself, but also training of employees, replacement of complementary equipment and installation costs, which constitutes a significant barrier that slows adoption (Hall & Khan, 2003; Tajuddin, 2025). The financial barrier is amplified by uncertainty about the performance of new technology. When the uncertainty is high, firms tend to delay adoption, since premature investments in new technology can quickly lead to substantial sunk costs, which firms want to avoid (Hall & Khan, 2003).

The mining industry presents a particularly challenging context for the adoption of new technology. Ediriweera & Wiewiora (2021) identify several specific characteristics of the mining industry that together prevent the adoption of new technologies. The capital-intensive nature of mining operations drives a strong preference for frequent short-term returns, making uncertain investments in unproven technology difficult to justify. Furthermore, productivity and performance metrics in mining are predominantly oriented toward efficiency and short-term production targets. This limits organizational willingness for the disruption that large-scale technological transitions can cause. Assimi et al. (2023) further highlight that mining companies tend to avoid unnecessary risk, as they are already exposed to high risk associated with their core operations. Together, these features suggest that the mining industry faces a combined set of preconditions that make technology transitions especially difficult to initiate and sustain.

In this context, several barriers surrounding the electrification of underground mining vehicles have been identified in previous research. While the findings are relevant to BEV adoption broadly, the literature does not explicitly address the specific type of vehicle this study investigates. Technologically, electric mining vehicles in underground mines face significant limitations in operating range due to the high energy demands of underground haulage cycles (Paraszczak et al., 2014). Electric mining vehicles carrying heavy loads up steep gradients require batteries with both high-power output and high energy capacity, making these underground vehicles among the most challenging to electrify (Assimi et al., 2023). A further consequence of requiring large battery packs is the drawback of a less favorable load weight ratio, which reduces the payload capacity and therefore the overall productivity of the operation (Paraszczak et al., 2014). The requirement for substantial charging infrastructure also represents an additional barrier, as the electric mining vehicle transition requires large upgrades to underground electrical systems. The investments in new power lines, substations, transformers, and other infrastructure components represent significant capital expenditures beyond the vehicle itself (Jacobs & Hodkiewicz, 2014). Charging time also introduces a productivity constraint compared to diesel refueling with ICE, as vehicles removed from operation during charging reduce the number of potential trips completed per shift, resulting in less material extracted to the surface (Martinetti et al., 2025; Assimi et al., 2023).

Concerns about driver resistance and insufficient education regarding the new technology prevent general BEV adoption (Sugihara et al., 2023). In the mining context, there are concerns regarding fire safety (Hooli & Halim, 2025) and new competencies that need to be developed regarding both maintaining and operating the electric mining vehicle (Assimi et al., 2023). Furthermore, the economic dimension represents one of the most significant barriers to the adoption. The high upfront capital investment that is required, combined with uncertainty around residual value and associated costs, results in a TCO that is unfavorable compared to ICE alternatives (Sugihara et al., 2023).

2.2 Business Model Innovation

A BM forms the foundation of how a company competes (Koprivnjak & Oberman Peterka, 2020). Teece (2010) argues that a BM explains how a company goes about value creation, value delivery and value capture.

Value creation is the process through which value is generated, utilizing resources, competencies and capabilities in the development (Achtenhagen et al., 2013), and results in a solution that solves a problem for the customer (Myler, 2014). The creation of value is not only about providing a product, but also the bundling with services to create synergy effects that enhance the value proposition (Kuijken et al., 2017), i.e. what value a solution provides a customer (Chesbrough, 2010; Adrodegari & Saccani, 2017). Ritala et al. (2013) suggest that value creation is a collective endeavor that not only delivers value to customers, but also to other stakeholders in the value chain. Macdonald et al. (2016) argue that value is judged on both organizational and individual levels. While BEV may help reach organizational goals for more sustainable operations, it might not consider the uptime that individual operators need to achieve a certain degree of efficiency. In the context of adoption of new technologies, such as BEV, in mining operations, value creation is not only about making an environmentally friendly truck that has the technical potential to perform operational duties, but also about incorporating additional services, such as charging solutions for lower downtime.

Value delivery is characterized by the architecture, channels and processes through which value is moved from one actor to another. This includes how suppliers reach their customers with their offering and how relationships are constructed, both with customers and partners (Kang & Kim, 2015). For equipment suppliers, that could be how to consistently deliver uptime to its customers, or collaborating with suppliers of charging infrastructure to develop a more holistic offer.
Value capture refers to how a firm makes a profit from the value that has been delivered (Ritala et al., 2013; Myler, 2014), which involves understanding how to make the BM financially sound using different revenue models (Gassmann et al., 2014). If uptime is the most important factor, offering as-a-service models to customers might be a valuable way to guarantee performance, while simultaneously collecting a premium for the additional generated value. According to a majority of studies on BM, value creation and value capture make up the two most central pillars (Biloshapka & Osiyevskyy, 2018). Sjödin et al. (2020) argue for the importance of developing the two concurrently and that they should be done together with the customer to ensure alignment. Value delivery is often left out or incorporated into one of the other two. For instance, Biloshapka & Osiyevskyy (2018) treat value delivery as a component embedded in value creation and value capture. Nevertheless,

this study examines value delivery as a distinct dimension, since it can help differentiate the BM without changing what value is actually delivered (Kang & Kim, 2015).

Building on this understanding of what constitutes a BM, BMI is the process of how to develop new value and how to capture that value (Sjödin et al., 2020). The approach typically outlines going from idea to successful commercialization of that idea (Broekhuizen et al., 2018). Moradi et al. (2021) and Gassmann et al. (2014) argue that BMI is more important than any product or service innovation in isolation. BMs are needed to successfully commercialize the potential of new technologies (Chesbrough, 2010) and BMI is gaining significant attention from manufacturing companies as a priority (Thomson et al., 2023). There are several instances of companies that have had a strong innovation program for new products and services but have failed nevertheless. Gassmann et al. (2014) argue that this is because changing environments require BMs to be adapted to enable competitive advantage. This need for adaptation comes from new dynamics such as shifting expectations from customers, new technological advancements and deregulations, which have created an imperative for new BMs that seize opportunities with the new dynamics (Ramdani et al., 2019). The mining industry is no exception to this and there are examples of shifting dynamics. Regulations create pressure for reducing emissions (Fossilfritt Sverige, 2022), rapid advancements in battery technology shorten technology lifespan (Ezugwu et al., 2025), and shifting customer requirements create higher demand for sustainability and operational efficiency (Guerin, 2020). Therefore, simply developing a new truck is not sufficient to sustain a competitive offer. The recognition of BMI's importance is growing. Nonetheless, the research on BMI processes in advanced industrial B2B contexts is underexplored (Thomson et al., 2023), motivating further studies on how BMI is currently done in B2B settings.

Despite this importance, developing and implementing new BMs is rarely straightforward. Past research has found that new BMs often collide with existing ones, creating tensions that must be managed (Amit & Zott, 2001). Adding further complexity, Chesbrough (2010) argues that managers are in doubt regarding what configuration of BM will have highest potential for successful commercialization. This is especially true if there exists a dominant thought process regarding what is important with the current technology and market, which leads to missed opportunities. These challenges are compounded by "strategic trade-offs" that exist regarding how to set up new BMs (Broekhuizen et al., 2018). These include the level of dependence of the existing organization, the level of flexibility in the development, how to deal with the incumbent BMs, and finally if and when the original value proposition should be changed. Previous literature argues for high level of independence, high level of flexibility, and challenging the status quo while sticking to the original value proposition to create consistency. Broekhuizen et al. (2018), however, have found that managers tackle these trade-offs differently and a clear directive on how to act is not always the same. The authors argue for instance that if compatibility with existing business is needed, a high level of independence might not be favorable.

Given these inherent uncertainties, experimentation and iterative learning have emerged as key approaches to BMI. Rather than designing a complete BM up-front, gradual refinement through exposing customers to new models and learning from their responses can facilitate more successful BMI (Chesbrough, 2010; Achtenhagen et al., 2013). What value is to be delivered and how to capture that through different revenue models needs to be tested and evaluated for new industrial solutions (Thomson et al., 2023). Thomson et al. (2023) propose BM piloting as a tool for handling the uncertainties of new technologies and their performance levels and "solution scalability" in an industrial setting. Before testing whether a BM works at a larger scale, a targeted market can be used to evaluate its potential and address vulnerabilities with introducing a new technology (Geissdoerfer et al., 2022). During BMI piloting, value creation and value capture need to be aligned, meaning that what to offer and which revenue model to use needs to be coordinated (Thomson et al., 2023).

How BMI is developed in practice is shaped by the relational context in which it occurs, particularly in complex industrial settings like mining. Therefore, companies must find and develop new partners and cultivate new relationships that can help sustain the demands of the new BM (Broekhuizen et al., 2018). Involving suppliers and other actors in collective development can be a powerful method to strengthen new BMs' outcomes. Through this, a company can achieve better cost efficiency and enhance innovation capabilities (Chesbrough & Schwartz, 2007), but the nature of these partnerships matters significantly, especially in industries with complex operations. Guerin (2020) has studied the impact suppliers can have on mining companies trying to transition to more sustainable solutions. He found that there are barriers to this which are mainly cultural. The mining industry's conservative culture presents significant challenges to transition to new technologies, such as BEV. Overcoming this resistance requires a different kind of supplier-customer relationship. Guerin (2020) found that a key constraint mining companies have regarding increasing engagement with suppliers is the lack of insights suppliers possess of their operations. A major reason for engaging with suppliers is whether they can create a more tailored offering that specifically tackles the mining company's need: such as higher efficiency and reduced costs. This requires a more engaged relationship in which suppliers understand the customer's business and how their products impact mining operations (Guerin, 2020). An increased relationship with customers in isolation is not enough to develop new BMs. It happens in an ecosystem, involving equipment suppliers, energy providers, infrastructure companies and other partners (Rachinger & Müller, 2024). Due to the interdependencies that arise, a structured coordination and orchestration process is needed, which means new forms of collaboration with partners (Rachinger & Müller, 2024). Without structure and alignment, value creation risks becoming fragmented. Customers require more complete solutions that not only include a product, but also supporting functions such as charging infrastructure, to create a more holistic value proposition (Rachinger & Müller, 2024).

While BMI describes reconfiguration of value creation, delivery and capture, it does not specify the mechanism through which this reconfiguration occurs. In industrial manufacturing contexts, servitization represents a primary form of BMI that suppliers use to address customer adoption barriers and to increase the value proposition.

2.3 Servitization

Traditionally, relationships between supplier and customer have been transactional and solely focused on providing a product, while the buyer takes on all operational risks with using that product (Cannon & Perreault, 1999). Servitization represents a fundamental departure from this model. The trend among industrial firms is a shift from product-oriented BM towards service-oriented models (Adrodegari & Saccani, 2017). The servitization concept describes the transformational process where a manufacturer shifts from a purely product-oriented BM to a more service-oriented approach (Kowalkowski et al., 2017). It was initially termed to describe the phenomenon of manufacturers combining their core product offering together with services to generate additional revenue and to broaden their position in the value chain. Servitization has since evolved into a wider strategic imperative (Perona et al., 2017; Lightfoot et al., 2013). The manufacturing company of today views this shift towards servitization not merely as adding basic after-sales support, but as a fundamental innovation of how the organizational capabilities can better create mutual value through integrated product-service offerings (Perona et al., 2017). By transitioning towards servitization, manufacturers hope to achieve more stable and recurring revenue streams and the ability to differentiate themselves from competitors and other low-cost alternatives (Lightfoot et al., 2013; Doni et al., 2019; Baines et al., 2017). Additionally, customers benefit from having their needs fulfilled in a more sustainable way and from achieving significant cost reductions through the services provided. Suppliers can utilize their resources to provide services around the product that help achieve better customer outcomes and consequently create more value. However, as will be discussed, this transition is neither linear nor a guarantee to achieve these anticipated returns.

To successfully servitize an offering, companies often adopt a Product-Service System (PSS) framework (Baines & Lightfoot, 2013). In contrast to a transaction-oriented model where the ownership, operational responsibility, and asset management lie entirely with the customer, a PSS framework represents a shift toward a relational and performance-based arrangement (Baines & Lightfoot, 2013). Rather than capturing value solely through the initial product, and spare parts sale, the manufacturer takes responsibility for the provided equipment's performance and ongoing service, and through this receives payment as the customer utilizes the solution the equipment provides. Therefore, the perceived value for the customer shifts from the physical product itself to the delivered service and overall solution, where the product acts as the primary enabler of value (Orellano et al., 2017; Oliva & Kallenberg, 2003). The PSS arrangement also implies that the provider takes on risks that the customers sometimes are unwilling or unable to bear, and by assuming these risks the provider can charge a premium, generating additional revenue. This reframes PSS as a mechanism for strategic value redistribution rather than merely an additional service burden (Reim et al., 2016; Tukker, 2004).

The literature commonly classifies the spectrum of servitization into three distinct levels of PSS, ranging from basic product provision to advanced service contracts (Lightfoot et al., 2013; Tukker, 2004). These levels consist of different distributions of risk, responsibility, and value between the supplier and the customer. This distinction is particularly important to understand in capital-intensive industries where operational continuity is of high value.

Using Tukker's (2004) classifications, the spectrum begins with product-oriented services, where at this foundational level, the BM is still primarily focused on product sales, but with the provision of supplementary services like maintenance contracts, advice and consultancy to ensure that the product functions as intended and provides optimal use. The revenue model at this level remains largely transactional and product-oriented. Moving further along the spectrum, use-oriented services represent a shift from selling the product itself toward selling its availability or use. The provider generally retains ownership of the equipment and therefore takes responsibility for its maintenance, repair, and control. The product is often made available to the user through rental or leasing arrangements, and this model often requires long-term customer-supplier relationship. At the other end of the spectrum lies the Result-oriented services which are the most complex and advanced level of PSS. With this BM, the supplier and customer agree upon a specific delivered outcome, and there is no predetermined physical product that is tied to the transaction. The provider sells a guaranteed output or functional result, and therefore assumes full responsibility for managing the process. With this model, the customer pays solely for the actual performance outcomes, or "value-in-use" rather than the asset itself (Tukker, 2004). While these three levels are conceptualized as a linear progression, servitization paths are not always uniform. Matthyssens & Vandenbempt (2010) argue that depending on market characteristics and resource limitations, different firms take different and sometimes simultaneous paths rather than evolving in a strictly linear mode. This is often the case for capital-intensive industries where operational constraints and customer heterogeneity may prevent firms from following a straight path towards fully result-oriented models.

2.4 The Challenge of Servitization and its Consequences

While a successful progression toward result-oriented services promises higher profit margins and often higher customer loyalty, it introduces significant internal and external challenges for the manufacturer (Raddats et al., 2019). When companies underestimate the complexity of this transition, they often fall victim to what Gebauer et al. (2005) identify as the service paradox. In this scenario, manufacturing companies invest heavily in extending their service ability, leading to increased costs and expanded service offerings, but fail to translate these investments into expected higher financial returns. This paradox is further supported by large-scale empirical evidence where Neely (2008), in a study of over 10 000 firms, found that servitized manufacturers generated lower profit margins than their pure product counterpart, implying that rather than being exceptional, the transition's financial risks are systematic. The paradox often arises because delivering advanced services requires fundamentally different organizational structures, cultures, and capabilities than traditional manufacturing. Consequently, the paradox is often driven by clashing worldviews between production and service mentalities (Kastalli & Van Looy, 2013). The authors further explain that traditional manufacturing culture focuses heavily on standardization and efficiency, which is often in direct contradiction to the heterogeneity and flexibility required for advanced service provision. This tension is further aggravated by an overemphasis on tangible product characteristics and risk aversion, where managers view advanced outcome-based services as moving too far away from their traditional core competencies. Raddats et al. (2019) further explain that the transition involves actual operational and financial risks. If firms lack the necessary service management ability or fail to align their internal structures, the transition does not always increase a firm's chance of survival and often increases its exposure to failure and bankruptcy. Therefore, overcoming the service paradox requires not just adding services, but fundamentally innovating the BM to manage these new risks (Kastalli & Van Looy, 2013).

When manufacturers fail to overcome the barriers of the service paradox described above, the transition to services often stalls or reverses (Gebauer et al., 2005). Firms frequently adjust or reverse their service strategies, leading to two distinct but related countertrends: deservitization, the transformational process where a company shifts from a service-oriented to a product-oriented BM and service dilution, the process of reducing the service portfolio (Kowalkowski et al., 2017). The author also note that deservitization is not always a response to failure, and that it can equally represent a strategic repositioning where firms retreat from services because of market conditions that do not justify the associated costs. Parida et al. (2014) describe that one primary reason for this strategic retreat is the failure to manage the comprehensive organizational transformation that is required for these complex services. Merely adding simple services to an existing product offering, without developing healthy organizational capabilities, is negatively associated with financial performance. To succeed, manufacturers must develop their core abilities such as managing service delivery networks and integrated development processes. If a firm lacks these abilities and fails to align its BM, the anticipated financial gains will not be realized, which can force the firm to retreat to a product-oriented focus.

The fallback from advanced services is often closely linked to the operational risk that PSS exposes the manufacturers to, including severe delivery competence risks, technical risks, and behavioral risks (Reim et al., 2016). While providers can attempt to mitigate these, an inability to sustainably do so often leads to a strategy of risk avoidance. If the provider, in an effort to avoid these risks, decides not to offer the service at all, or refuses to take responsibility for the machine's condition, these actions will effectively constitute deservitization (Reim et al., 2016).

3 Method

This chapter outlines the different methods that were used when conducting this thesis. The aim was to ensure transparency and reliability in the research process, as well as to provide readers with an understanding of the study's credibility. The methods were designed to identify the barriers of BEV adoption, and to provide systematic insights into how equipment suppliers employ BMI to address adoption barriers for BEVs in the mining industry.

3.1 Industrial Context

This study examines how a supplier company develops new BMs to enable the adoption of a new product like BEV in a traditional industrial context. The focal company is Volvo Trucks (VT) which is a major Swedish equipment supplier and a current frontrunner of the BEV transition in Europe. To get the customer's perspective, which is necessary to determine the existing barriers and how value propositions are evaluated, one of VT's mining customers was also studied. Bedrock Co (BC) is a large Swedish mining company operating several large mines in Sweden and actively pursuing electrification. The case was selected based on two main criteria. First, accessibility through established contacts at VT and their existing relationship with BC. Second, its representativeness, as VT operates at the frontier of mining electrification, while BC reflects the strategic and operational realities of a large-scale Swedish mining operation that is navigating this transition.

Volvo Group (VG) is the global consortium comprising several business units, including VT, Volvo Construction Equipment (VCE), Volvo Energy (VE), Volvo Financial Services (VFS), and Volvo Connected Solutions (VCS). While VT is the main focus of this study, the business units collaborate, meaning other business units will be referred to as well. For example, VCE has implemented BM elements that can guide VT's own development, and VE provides energy-related solutions that complement VT's offering. In this thesis, VG is used when referring to shared group-level functions, and VT when referring to truck-specific operations and decisions. Furthermore, an explanation of the sales process (Figure 1) is relevant to better understand the case. The VG factory produces a truck that has been designed and developed by VG's development department. The VT organization sells the truck to dealers, that in turn sell the truck to the mining customers. Volvo Financial Services (VFS) provides financing solutions for the dealers and customers. While VT itself provides services through its dealer and service network, additional services for data collection are handled through VCS, and charging solutions are provided by VE. Furthermore, contractors operate in this value chain in providing truck services for BC and other mining customers. In these agreements, the contractor is responsible for parts of the mine's operation, and the mining company pays a usage-based fee for the contractor's service. While these agreements are quite common, they are not the focus of this study.

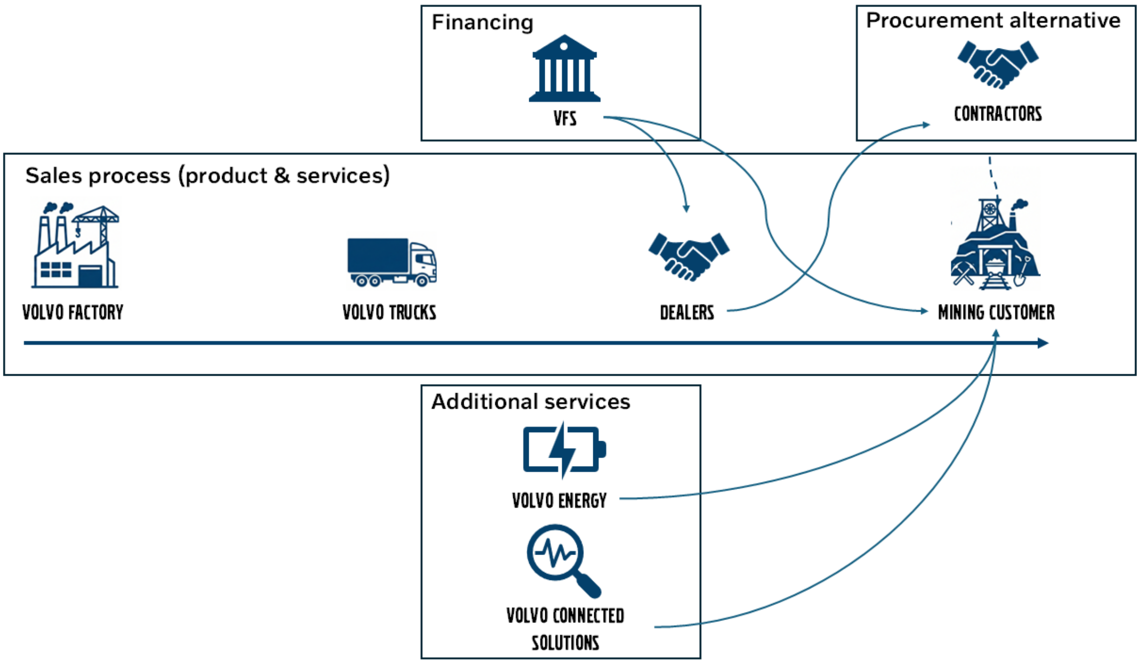

Figure 3.1: Volvo Trucks Sales Process

3.2 Research Design

This study follows a qualitative case study design. Yin (2018) describes this design as a suitable way to investigate "how" and "why" questions in a real-world industry setting especially where boundaries between phenomenon and context are not clear. This research was designed as an instrumental case study (Stake, 1995). With this approach we aimed to use VT as a representation to provide insights into barriers of BEV adoption and how equipment suppliers in the broader mining industry configure their BMs and work with BMI in response to BEV adoption barriers. By examining this specific case, the study aimed to provide guidance for how BMI can facilitate the wider adoption of BEV across the mining industry. The primary empirical data was collected through semi-structured interviews within VG's business units, as well as BC.

The research followed an abductive approach that is defined as an iterative movement between theoretical frameworks and empirical data (Bell et al., 2019; Dubois & Gadde, 2002). A theoretical foundation in adoption barriers, BMI, and servitization guided our interview design and initial analysis. With this in mind, we were open to circle back to theory if new and unexpected patterns or adoption barriers arose during our interviews to further deepen our understanding through new theoretical viewpoints.

3.3 Data Collection

In our research, semi-structured interviews served as the primary data source, and were used to explore how VT works with BMI to overcome adoption barriers for BEV. These were complemented by an on-site observation of one of BC's Swedish mines as well as a review of selected internal documentation, both of which provided additional context to the primary interview data.

3.3.1 Data Collection Methods

Due to the exploratory nature of the study, interviews are suitable to capture relevant data that are rich in detail (Denscombe, 2010). The level of flexibility offered by interviews also allowed us to steer the interaction towards relevant talking points (Denscombe, 2010). This type of method also allowed us to gather a wide range of perspectives from different individuals with different roles and responsibilities (Bell et al., 2019). The interviews with the VG business units allowed us to gather a wide range of insights into how equipment suppliers work with BMI, as well as how they interact with mining customers. The interviews with BC enabled a better understanding of what mining customers believe are necessary components of the value proposition, as well as how they believe that can be achieved. By covering both perspectives, the study was able to find gaps in expectations, which can be important improvement points for the supplier. The interviews were conducted with a semi-structured approach, which enabled responses to predetermined questions that were relevant, but also allowed the respondents to expand on other subjects that may provide interesting inputs (Bell et al., 2019). To facilitate a semi-structured approach, two interview guides (Appendix A) were constructed that allowed for flexibility within a focused theme. One guide was constructed for VG interviews and another for BC interviews. The guides contained relevant talking points and questions that we wanted to cover. The questions were selected and modified depending on the role of the respondent. Since the research covered a broader set of questions than any single respondent could address, different questions were targeted depending on the role of the respondent. This meant that certain topics were explored more in depth with specific roles, while other topics were prioritized with others. This ensured comprehensive coverage across the complete interview series. Before the interview took place, participants were notified about their participation and how their answers would be used. The interviews were conducted either online through Microsoft Teams or in person depending on the respondents' preferences. Each interview lasted between 45 and 60 minutes. Furthermore, the interviews were, with the approval of the participant, recorded and transcribed using the built-in Microsoft Teams function. This offered several benefits and it allowed us to focus on the conversation rather than taking detailed notes and also ensuring that no important points were missed (Bell et al., 2019). The interviews were held in English or Swedish in accordance with the interviewee's preference, but any used quotes were later translated to English manually with the aim of staying as close to the original wording as possible.

To complement the data collected from the interviews, internal documentation was reviewed. The documents that were reviewed depended on availability and suitability, meaning that only non-confidential documents applicable to the study were reviewed. The documents provided contextual understanding of organizational strategies as well as some background knowledge regarding the mining process.

During the early phases of the study, a visit to one of BC's mining sites in Sweden was conducted. The observation provided us with direct insights into the physical condition of the underground mining operations. Witnessing the operational environment firsthand facilitated a better understanding of the practical constraints that the BEV would need to meet. The informal setting of the site visit enabled a more casual conversation with operational personnel, with insights into day-to-day priorities and concerns that are not always touched upon in formal interview settings. These observations informed the development of more targeted and operationally grounded questions for the interview guide.

3.3.2 Data Collection Sampling

A purposive sampling strategy was employed, with participants strategically selected based on their relevant experience. This ensured that the sample units were best suited to contribute to the study's objectives (Bell et al., 2019). This was complemented by snowball sampling, where interviewees recommended additional relevant participants within their organizations, which helped identify key persons that otherwise might have been overlooked (Bell et al., 2019). In total, 17 interviews were conducted with a 14-3 split between employees within VG and BC. A list of respondents is displayed in Table 1. The larger proportion of interviews at VG reflects the focus on the supplier perspective in this study as well as the greater availability of participants there. Despite the limited access to BC interviewees, three interviews were conducted with key roles involved in procurement and operational decision-making. The interviewees were selected based on their relevance as well as direct involvement in the electrification decision-making process, BMI development, or operational implementation of BEV.

While BC respondents provided the mining customer perspective on BEV adoption barriers, VG respondents contributed with broader industry perspectives based on their exposure as a large supplier across multiple mining customers. This extended the empirical foundation for RQ1 beyond the specific customer-supplier case with BC. In most cases, the supplier observations were independently confirmed by BC respondents, thereby strengthening the credibility of those findings.

To understand how BMI initiatives are developed and implemented from the supplier's perspective, the aim was to interview employees with different key roles within the VG organization. Roles were carefully considered together with the supervisor at VT.

Table 3.1: Overview of interviews

Code #	Role of respondent	Area of work	Company
VG-1	Senior Strategy Executive	Business development	VT
VG-2	Digital Solutions Manager	Digital services	VG
VG-3	Fleet Sales Manager	Business development	VCE
VG-4	Fleet Manager	Business development	VFS
VG-5	Senior Strategy Executive	Business development	VCE
VG-6	Services Manager	Services	VT
VG-7	Senior Sales Executive	Sales	VT
VG-8	Senior Services Executive	Services	VT
VG-9	Strategy Manager	Services	VE
VG-10	Senior Strategy Executive	Business development	VT
VG-11	Senior Sales Executive	Sales	VT
VG-12	Senior Services Executive	Services	VT
VG-13	Services Manager	Services	VT
VG-14	Sales Manager	Sales	VT
BC-1	Sourcing Manager	Sourcing	BC
BC-2	BEV Project Manager	Electrification	BC
BC-3	Electrification Program Manager	Operation Strategy	BC

3.4 Data Analysis

The qualitative data gathered from the semi-structured interviews was analyzed using the Gioia methodology, which is a systematic inductive approach designed to ensure qualitative rigor while still allowing for new concept development (Gioia et al., 2013). The methodology was selected because it is well suited for exploratory research that aims to understand how and why different phenomena occur. This aligns well with the research questions of the study. Gioia et al. (2013) further argue that the method is grounded in the assumption that organizational participants are knowledgeable in their field and that they can explain their own experiences. It also assumes that we in the role as authors can accurately represent that knowledge and experiences while also developing theoretically relevant interpretations.

The analysis was conducted through two interconnected levels. In the first analysis, the raw quotes from the transcripts were summarized into shorter first-order concepts that captured the essence of what the respondent expressed and at the same time tried to retain their original language and meaning (Gioia et al., 2013). This generated a large number of initial codes that amounted to a total of 450. These were then compared to each other to reduce them to a more manageable set. Where different respondents expressed the same idea, used very similar language, or expressed the same underlying meaning, their corresponding 1st order concepts were combined. This together with the removal of non-relevant data resulted in 45 1st order concepts.

In the second analysis, the 1st order concepts were grouped into broader themes with some connections to the already established theoretical themes from the literature chapter. This allowed the 2nd order themes to move into a higher level of abstraction regarding what the 1st order concepts suggested about the underlying phenomena (Gioia et al., 2013). In total 11 2nd order themes were identified. These 2nd order themes were then further grouped together into 3 aggregate dimensions, representing overarching concepts from the data (Magnani & Gioia, 2023). The full progression from raw quotes to 1st order concepts to 2nd order themes to aggregate dimensions was constructed in a data structure in Excel. This provides a transparent and visual representation of how the analysis moved from raw data to theoretical concepts. As Gioia et al. (2013) explain, this structure is a central part of the methodology because it makes the connections between the raw data and the emerging theory and findings easily traceable for the reader. The development of the data structure was iterative rather than linear. As the results chapter was written, certain 1st order concepts and 2nd order themes were revisited and reorganized where the data suggested a different grouping that was more analytically coherent.

To reduce individual bias and strengthen the credibility of the analysis, both authors were present at all interviews and independently extracted raw quotes from the transcripts and coded them before comparing and discussing our interpretations. Where disagreements arose, they were resolved through discussion and explanation of our individual interpretations. The process of independent coding followed by discussions helped ensure that the final interpretations were grounded in the data rather than in individual preconceptions. Since the coding was conducted in Excel it allowed us to keep all raw data points readily accessible making it easy to move back and forth between the original transcripts and the codes.

3.5 Methodological Limitations

While the chosen methodology was suitable for investigating the research questions stated in section 1.3, there are, however, limitations to the generalizability of the findings. VT is a frontrunner in BEV electrification, and this means that its BMI initiatives are likely more developed than those of other suppliers in the industry, and therefore the findings may have limited transferability to less advanced suppliers. The same logic applies to BC, as they represent a large, capital-heavy mining company that is actively pursuing electrification. This means that their perspective on adoption barriers and willingness to engage with new commercial arrangements and unproven technology may not be representative of smaller mining customers. Furthermore, this study was conducted at a specific point in time in a rapidly evolving market, which means that the findings regarding technology readiness or BMI maturity may shift significantly as BEV technology develops.

Given the availability of participants for the interviews, there is a sample size imbalance between VG and BC. With only three BC interviews conducted compared to 14 within VG, this limits the depth of the demand-side perspective. The customer perspective on BEV adoption barriers is based on a relatively small sample, which may not capture the full diversity of the experiences and priorities within the customer organization. It should be noted, however, that the VG respondents contributed broader industry perspectives on adoption barriers grounded in their market exposure across multiple mining customers within Sweden. While this extends the empirical foundation for RQ1 beyond the specific case study, the limited number of BC interviews means that the direct customer perspective on barriers remains the most constrained part of the results. The study also only investigates perceptions and experiences but cannot quantify the relative magnitude of different barriers beyond what respondents themselves emphasize, thereby limiting the precision of conclusions.

3.6 Ethics

Several ethical considerations were addressed in this study. All interviewees provided informed consent after being given the full information about the study's purpose and methods before participating (Bell et al., 2019). All interviews were conducted on a voluntary basis, and they could choose not to answer specific questions without providing a reason. To protect the privacy of individual respondents, all interviews were anonymized using generalized role labels as well as a coding system as presented in section 3.3.2. All interviews were recorded and transcribed with the approval of each respondent. These files were handled confidentially throughout the research process, and in the end deleted.

We recognize our dual role in this study as both academic researchers associated with Chalmers University of Technology and as collaborators with VG. This dual role was communicated transparently to all participants throughout the study so that they could make a fully informed decision about their participation.

3.7 Use of AI tools

The use of AI tools has had three primary functions in this thesis. First, Claude (Anthropic) was used to improve the language including improving grammar, spell-checking, increasing the readability and improving the structure of the text. Second, Scopus AI was used to find relevant articles for the theoretical background. The prompts asked for articles on certain topics and while identification was possible, all articles were assessed manually to check relevance. Third, AI was used to create pictures and graphs, e.g. the picture on the first page and constructing the Gioia tree graph. While all content and arguments presented were produced by the authors, AI was used to support idea development and to critically evaluate arguments and conclusions. All proposed changes by AI were revised and challenged manually. Lastly, no company sensitive data was uploaded and full confidentiality was followed during the thesis work.

4

Results

This chapter presents the findings from the data collection. The first section captures the barriers found in the interviews while the remaining sections focus on how VT works with BMI and the organizational conditions that are required to realize the potential of BMI. Figures 4.1-4.3 show the data categorized using the Gioia methodology.

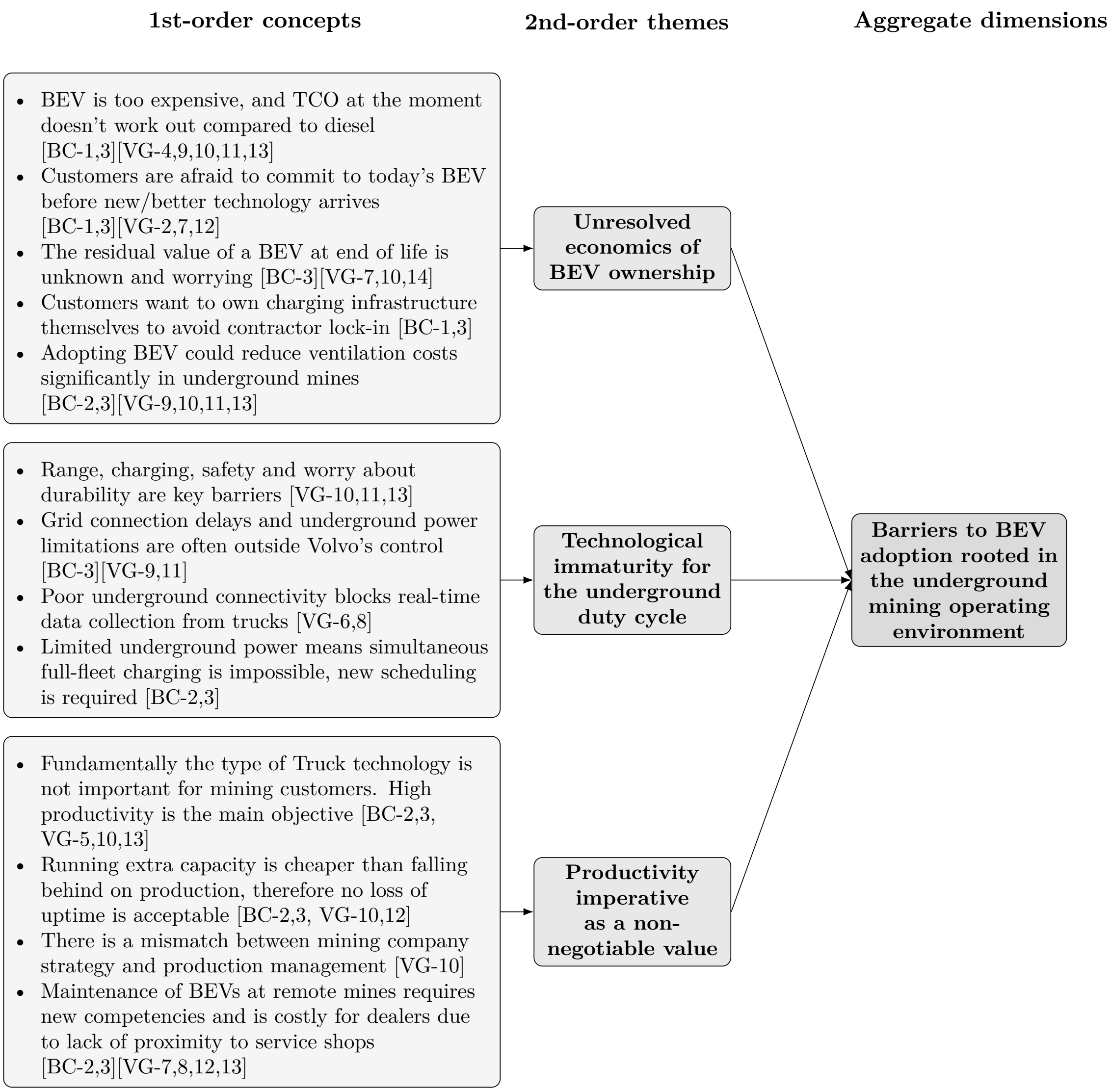

Figure 4.1: Data structure (Part 1 of 3).

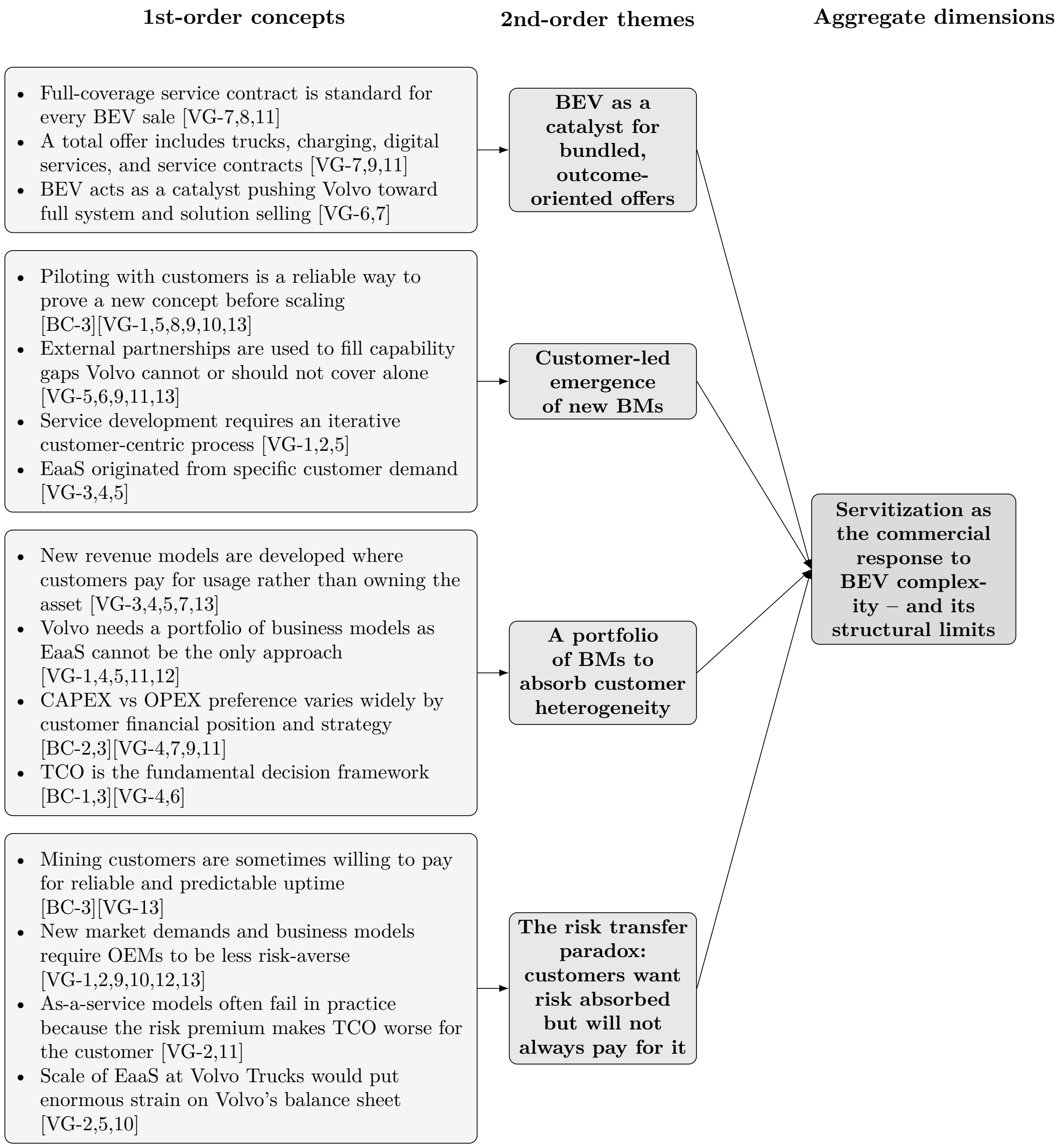

Figure 4.2: Data structure (Part 2 of 3).

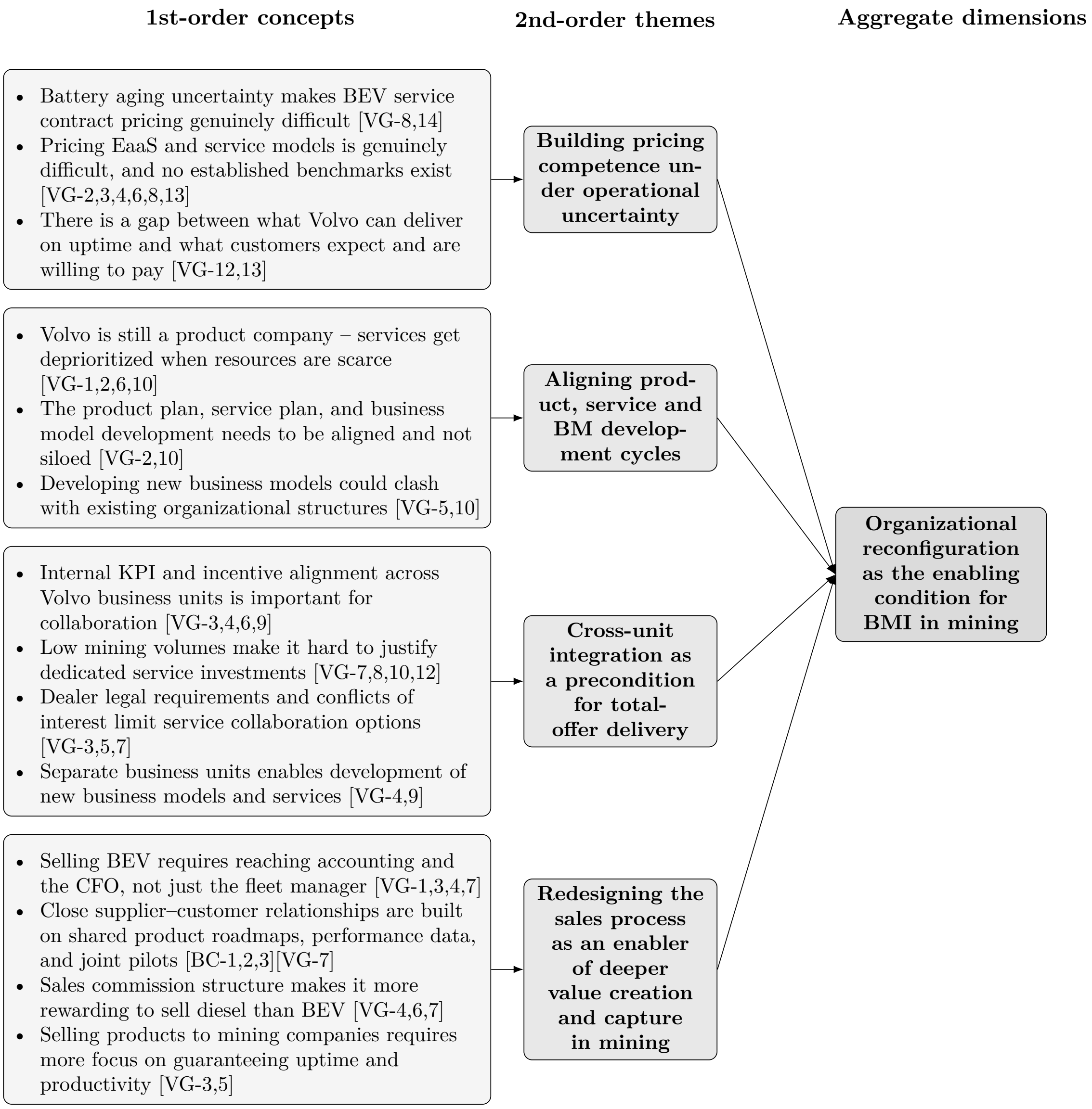

Figure 4.3: Data structure (Part 3 of 3).

4.1 Barriers to BEV Adoption Rooted in the Underground Mining Environment

The operating environment of mining creates substantially greater demands on trucks than conventional open-road transportation. Vehicles experience heavy loads, which causes stress, both during transportation, but also during loading and unloading. The roads are uneven and harsh, resulting in substantial wheel degradation. The steep gradients in underground mining require strong engines and high energy usage, especially when carrying heavy loads. These conditions accelerate mechanical wear and put additional service demands, placing high demands on operational reliability. The barriers presented in this section are primarily based on interviews with both VG and BC, but also from the site observations at the BC mine. While the accounts from mining customers provide direct operational perspective, findings from VG interviews were in most cases supported by BC respondents.

4.1.1 Unresolved Economics of BEV Ownership

The most frequently identified barrier across both VG and BC interviews is the increased investment required when transitioning from ICE to BEV. The current TCO for BEV is substantially higher than that of the equivalent ICE model, driven primarily by the higher purchase price. As will be discussed in later sections, the longer energy replenishment time and lower payload require more trucks in the operation to carry out the same work, leading to more investments in trucks, adding to the financial burden. The gap in TCO is heavily impacted by fluctuation in diesel prices. As one respondent argued, drops in diesel price, which Sweden experienced up until end of 2025, reduces the operational cost advantages for BEV over its lifetime. Adding to the financial constraint, several respondents highlighted that the TCO is affected by residual value, which as of today is largely unknown. Customers therefore face difficulties when calculating total lifetime costs, adding to the financial uncertainty. Adopting BEV also requires investments in charging infrastructure that alone represents high expenditures, further weakening the economic case for BEV. To limit lock-in effects, the charging infrastructure is something that BC wants to own themselves. If one contractor were to supply the charging infrastructure, that contractor would have leverage over BC and limit their ability to switch suppliers.

While the high investment cost is a significant barrier, there might be savings in other areas. Respondents from BC highlighted that ventilation costs constitute a significant operational expenditure, a finding echoed by VG respondents who reported similar feedback from other customers. BC respondents believe that the introduction of BEV in the mining environment can help reduce ventilation requirements extensively, due to reduced heat and harmful emissions from vehicles. However, BC argued that they need to fully electrify all underground operations in the mine to reduce the ventilation demand, meaning partial BEV adoption delivers negligible reduction in ventilation costs. Therefore, the economic barrier is still very relevant as of today.

Even though there might be non-monetary incentives to invest in BEV, these alone cannot currently justify the extra costs associated with the adoption of BEV. However, VG and BC respondents revealed that achieving full TCO parity is not an absolute requirement. Rather, the TCO only needs to reach an acceptable financial level given the non-economic advantages, such as lower emissions, better working environment and reputational value. Furthermore, BC expects the financial case for BEV to be strengthened over time, in line with future cost reduction in BEV technology. This implies that the barrier is understood as temporary rather than permanent.

Rapid technological development nonetheless introduces a separate and partially contradictory barrier of technology obsolescence. Acquisition of BEV entails a large financial investment, and committing capital to the current BEV generation causes concern regarding how to achieve full return on investment before the BEV-technology becomes outdated. According to a senior sales executive at VG, this concern regarding technology lock-in provides a rationale for delaying commitment until the technology stabilizes, suppressing the adoption rate. However, VG respondents argued that high sales volumes are required to achieve this high-paced technology development that would result in technology obsolescence risk. This creates a problematic dilemma that neither customer nor supplier can resolve on their own. Nevertheless, BC respondents see the short operational life of 3-4 years in the mining environment as an opportunity, since technology replacement happens more frequently, reducing the technology obsolescence risk.

4.1.2 Technological Immaturity for the Underground Duty Cycle

The current technological readiness of BEV in underground mining is a fundamental barrier mentioned by both customer and supplier perspective. Since costs for disruptions in ore production are exceptionally high, charging stops need to be kept to a minimum, as one senior sales executive stated, “Range is a qualifying criterion for running a BEV”. VT respondents noted that utilizing BEV at scale would require more sophisticated planning tools to forecast energy consumption and schedule charging windows to keep disruption to a minimum, which entails new investments. Parallel to the range barrier is the charging constraint, where BC respondents argued that transitioning to BEV would require substantial upgrades in grid connection to achieve a sufficient level of power to the mining site. Simultaneous charging is not currently feasible without battery storage systems and restructuring scheduling introduces its own challenges. The former would require additional financial investments, and the latter would increase organizational complexity due to the need for scheduling negotiations with the employee unions. Compounding this, charging infrastructure becomes progressively more difficult as the depth of the mine increases. Trucks operating continuously underground require charging solutions at depth, where high-power delivery is technically harder to achieve. Furthermore, to reach the level of power needed to charge several trucks simultaneously, the grid connection to the site needs to be upgraded. This problem is not easily solved and not under the control of VT, since it is difficult to influence utility companies and regulatory processes that have the decision power regarding expansion of the grid network. Even though VT can offer charging infrastructure solutions through other business units within VG, VT is still dependent on other actors.

Finally, there are concerns regarding the safety and durability of the BEV in the harsh mining environment. Even though the probability of fire ignition for BEV is lower compared to ICE, such an incident would be substantially more hazardous and damaging due to the chemistry of the batteries. Furthermore, since a fully proven BEV product for the heaviest underground duty cycles does not yet exist in commercial operation, how well current truck generations will hold up over a full asset lifetime under these conditions remains unresolved. Charger hardware also faces durability challenges, with dust and mechanical stress in underground environments creating maintenance demands that have not yet been fully characterized.

While there are barriers surrounding the current BEV technology, there are also concerns regarding the development of BEV. While VT has years of experience of ICE in mining operations, the development of the BEV requires substantial amounts of new data. Data which can be difficult to retrieve from the underground mining due to poor connectivity. Without real-time data, VT cannot confidently offer guarantees and uptime commitments and as will be discussed in the next section, achieving high productivity is non-negotiable. Furthermore, development efforts require large volumes to both acquire more data but also to motivate investments, and since sales volumes to mining customers are low, efforts are constrained.

4.1.3 Productivity Imperative as a Non-Negotiable Value

Achieving high productivity is a non-negotiable requirement in mining operations, and any technology that limits uptime is treated as operationally unacceptable. As one BC respondent stated, "Bedrock Co works with overcapacity because it is cheaper than falling behind on production." The ore's value means that downtime carries an immediate and substantial cost, making reliability the primary criterion by which any new technology is evaluated. The mining industry revolves around delivering high tonnage per hour at the lowest possible cost, which makes the choice of drivetrain secondary to whether it reliably delivers the required output. One BC respondent stated that while executive managers might want to invest in the newest green technology, operational managers focus more on reliability at the lowest cost since it gets very expensive when operations stall.

Respondents from VG noted that charging time might introduce a further productivity constraint that ICE does not present. Unlike diesel refueling, which takes minutes, BEV charging removes trucks from operation for extended periods. Respondents from BC agreed that charging demands more careful operations planning, but in many cases charging can be done during natural pauses such as shift breaks, meetings, lunch periods, or blasting windows when trucks cannot operate regardless.

Respondents from BC stated that current BEV technology cannot meet the high productivity demand at the same level as a conventional ICE in the most demanding underground applications. Mining trucks must carry heavy loads on steep gradients, requiring high energy usage and consequently large battery packs, directly affecting payload capacity. Additionally, respondents from both VT and BC are concerned that these conditions affect battery degradation in ways that are not well understood yet. This creates uncertainties around battery lifetime, which creates a high risk of needing to replace batteries before the end of the operational lifetime of the truck.

Service directly affects the uptime of the BEV, making it a productivity concern and servicing trucks at remote mine sites is both difficult and costly. Many mines are located far from dealers or workshops, and as one respondent from BC explained, mining trucks in most cases are not road-legal, therefore service must be conducted on site. This requires both physical space and qualified technicians to be available at the mine, which is costly and difficult to set up in confined spaces underground. Opening new service shops near mining sites is in many cases not viable due to lower volumes of trucks sold to this segment, and collaborating with third-party service providers is often not feasible. To maintain quality standards, VT needs to certify these actors, which is both time-consuming and costly. This affects ICE trucks as well but warrants specific consideration since several respondents argued that BEV technology aggravates this service challenge further. Servicing BEV requires new competencies and tools, and safety regulations limit who can perform the service. Therefore, the adoption of BEV increases the service complexity.

4.2 Servitization as the Commercial Response to BEV Complexity and its Structural Limits

The adoption barriers described in the previous section create conditions under which a product transaction alone cannot support BEV adoption. As a response to this, VG has shifted its BMI towards developing more bundled, outcome-oriented arrangements with surrounding service contracts, charging infrastructure, digital services, and in the most extreme cases, provided a full as-a-service model. This section describes how that shift emerged, what commercial forms it has taken, and where its limits lie.

4.2.1 BEV as a Catalyst for Bundled, Outcome-Oriented Offers

Several respondents at VT identified BEV not only as a new product, but as a driver of change in their BMs. A Service Manager at VT argued that shifting the company towards more BEV sales can act as a catalyst towards offering complete solutions, partly because BEV requires more systemic thinking in a way that ICE does not. This was further explained by a senior sales executive, that BEVs are sold with more additional services because customers feel they need more support, and that the price of the vehicle itself reduces customers' price sensitivity to the services that accompany it. Together these accounts suggest that BEV's cost and complexity altered the terms on which the customers engage with VT, partly because the product made a traditional standalone transaction not commercially sufficient for both parties. The mechanism underlying this shift is a transfer of risk. When adopting new and unfamiliar technology, customers become less willing to carry operational and financial uncertainty themselves. Respondents from BC argue that they expect the supplier to absorb more of it through packaged services. A respondent at VT agreed on this point that customers transition towards choosing total-offer service contracts aimed to offload risks associated with BEV adoption. One strategy executive framed this as a matter of fairness as much as commercial logic: "It is fair that if we push new technology onto our customers, Volvo should also be willing to take on the associated risk".

The most immediate commercial response to this shift was offering a full coverage service contract, internally referred to as the gold contract, as the default for every BEV sale. The contract covers maintenance, drivetrain, batteries, wear and tear, and digital applications for uptime support, with the intent of giving the customers the confidence to adopt BEV by removing their own service responsibility entirely. Two senior sales executives confirmed this in practice, and stated that the gold contract should be part of 100% of BEV sales, driven by customers' increased reliance on VT for information and services. First-time BEV buyers in particular asked for more comprehensive coverage due to inexperience, and the mining context intensified this further as underground wear and tear is significantly higher than in other applications. This makes the gold contract even more central to the BM and requires VT to develop detailed knowledge of site-specific conditions to price and honor it accurately. The gold contract also serves a dual logic, while it oversees customers' risk management, it also ensures that the service revenue and spare parts sales remain within VT rather than moving to third parties. A respondent stated the goal of this is not higher revenue, but rather retention of aftermarket income at a time when BEV's simpler drivetrain reduces overall parts volume.

Other than the service contract, respondents within VG described a broader commercial bundle referred to as a total offer. This included trucks, charging infrastructure, digital services and service contracts as an integrated package. There was a general consensus across several respondents within VG that a total offer must be provided, reflecting how deeply BEV's operational dependencies extend beyond the vehicle itself. One sales executive described it as a way to genuinely help the customer, arguing that VT needs to look more holistically at the entire system. Meaning that rather than focusing only on the truck, VT should understand how to facilitate additional products and services, such as charging infrastructure, battery management, and optimizing energy procurement to reduce costs.

4.2.2 Customer-Led Emergence of New BMs

The service bundling described in the previous section did not only emerge from internal strategic planning. New arrangements, including EaaS, originated from specific customer demands rather than top-down design. EaaS refers to an arrangement in which the customers pay for access and usage of the truck rather than owning the asset themselves. Several respondents at VG highlighted the benefits of EaaS: customers avoid tying up capital and can instead invest that capital toward their core business. VG's ownership and responsibility of the asset create an obligation to maximize uptime of the vehicle, and the customers receive a predictable cost structure instead of a traditional unpredictable maintenance expenditure. This model allows the customers to pay for usage, rather than purchasing ownership. A sales executive described this as an opportunity for both the customer and supplier regarding the technology obsolescence concern, by allowing more advanced trucks into the rotation as new generations become available, thereby allowing the suppliers to resell the truck at a viable residual value. The same respondent further argued that no customers want to invest three times as much to adopt a BEV compared to ICE, which they do not have to with EaaS. With that said, this setup increases the complexity of the contract. A fleet manager explained that this model requires VG to manage utilization risk contractually through different minimum usage fees, thereby guaranteeing a sufficient level of revenue in cases of underutilization of the asset.

The EaaS model was first developed within VCE. A respondent described it as originating as a direct response to a key mining and construction customer demand. This customer pull created the commercial, legal, and operational foundations that were later reused to scale the model more broadly. Thereafter they developed it together with other customers who were interested in the concept, growing it over time into an organizationally supported initiative with top management sponsorship and a dedicated regional setup. A respondent from VFS summarized this broader principle that what VG delivers is highly customer-driven. One senior strategy executive argued that BMI initiatives should be customer-driven and aimed at creating a win-win situation for both VG and the customer. Therefore, new initiatives are evaluated through pilots together with the customer. The same respondent argued that to succeed with such pilots, it is important to have a high-level sponsor to create enough buy-in. Some of these pilots also require more top-down push which requires bold managers to take initiative and drive the pilots.

While EaaS has been developed and proven within VCE, VT is in the process of developing its own equivalent competence, being able to draw on the knowledge and commercial foundations already established within VG's business units. The iterative customer-centric process through which this is developed was described by one VT respondent as an internal service development approach, requiring at least one customer to be in the loop before any initiative in development could begin. This way of working promotes understanding of the pain-points and possible gains from the customer's perspective. This was explicitly contrasted with the product development logic where concepts must be fully resolved before production can begin. The respondent further explained that "Services are instead iterated forward, you know it won't work at the start and then you work to make it function". Contrary to this, BC described a preference for running pilot projects with VT to proactively test new technology before broader commitment. A service executive at VT also noted that a pilot was a good way of testing whether on-site service delivery at a customer location was operationally feasible.

External partnerships also play an important role in filling functional gaps that VG could not or chose not to cover internally. A strategy manager stated that VG does not produce its own chargers, and does not handle its own cabling, groundwork, or electrical installations, therefore positioning itself more as an integrator rather than a full-stack provider. The respondent further explained that decisions about what to build internally versus what to source through partners were based on mapping existing competencies against strategic priorities. A strategy executive explained that VG both forms partnerships as well as investing in external companies to broaden the offering for the customer.

4.2.3 A Portfolio of BMs to Absorb Customer Heterogeneity

Several respondents consistently described the mining customer base as too heterogeneous for any single BM to accommodate all. Customers differ significantly in how they prefer to own and finance their equipment. Large and capital heavy mining customers often prefer to pay upfront and avoid paying interest, while others are more constrained by balance sheet considerations and prefer to keep assets off their books. Another respondent mentioned that government incentive structures add another layer of complexity, as most subsidy schemes for BEV are investment-based and therefore push customers toward more outright purchase regardless of what the supplier offers. Contrary to this, a fleet manager explained that sometimes even capital heavy mining companies do not necessarily want to tie up capital in trucks when they could invest it in their core operations or infrastructure instead. Multiple respondents within VG concluded that different markets and customers have different conditions, making it difficult to have a single BM strategy for everyone, and that a wide portfolio is needed. Despite this variation, the TCO remains the common reference point across all BMs and all customers. Every BM with BEV, is according to several respondents within VG and BC ultimately valued against what it costs compared to running diesel trucks.

The customer heterogeneity also calls for VT to be able to achieve high customization of their offerings. In the case of development of new BMs, one senior strategy executive pointed out that a high degree of freedom is encouraged at an early stage, but over time, more standardized solutions are required. Furthermore, the same respondent argued that small sales volume, such as for the mining industry, is not a barrier to testing different BMs, and it is important to understand that in the end there is no size that fits all customers. Therefore, VT needs to be able to achieve a balance in the portfolio that both satisfies different customer needs but is also scalable. With that said, both VG and BC respondents described a broader pattern regarding the preference for ownership and control. BC respondents consistently expressed a desire for retaining ownership and operational control over assets and processes the closer they are to the core extraction activity. Trucks that are more directly involved in ore haulage carry a strong ownership preference where the mining customers want the full control of the asset.

4.2.4 The Risk Transfer Paradox: Customers Want Risk Absorbed but Will Not Always Pay for it

Mining customers want the supplier to carry the risk of BEV adoption, but the data from interviews show that only some are willing to pay for it. Multiple respondents at VG described the customer rationale as moving towards more comprehensive service contracts specifically to offload the risk that comes with an expensive and unfamiliar electric drivetrain and battery technology. From the BC perspective, this was directly confirmed as they expressed interest in paying for uptime guarantees and a guaranteed battery lifespan through a service agreement, stating they are willing to pay a premium for it. A digital solutions manager at VG framed the underlying logic associated with risk as something not to get rid of, but to search for in the customers' operations and take care of, as that is something they are willing to pay for. Another respondent argued that VT needs to be willing to take a calculated risk with the sale of BEV while at the same time being able to charge a premium for doing so. However, a respondent at VT noted that it varies among customers whether they are willing to pay for VT to carry the risk, and that "in general, they probably are not". Regarding EaaS, one senior strategy executive argued that the demand for EaaS has not been fully established due to the increase in price because of the higher risk transfer. Furthermore, a sourcing manager within BC explained that when contractors price BEV haulage, they face a similar problem, because the costs for BEV operations are uncertain, they are forced to add a risk premium, which makes the offer expensive. A contractor that commits early may find themselves competing in future procurement rounds against ICE alternatives with a lower TCO, and that is an exposure that customers expect the supplier of BEV to help manage.

This is where the structural contradiction is, as one product manager at VT described, as-a-service models are frequently pushed by external consultants and approved at leadership level, but they often fail in implementation. Because when someone takes on more risk, they need to be compensated for it, and when the price goes up to cover that risk, the TCO no longer holds. The same respondent further explained that "the customer does not value risk minimization, because it simply becomes too expensive". A VT fleet manager described that the offer that removes balance sheet exposure and guarantees uptime requires convincing the customer that the broader financial picture still makes sense. A respondent further argued that VG should be able to carry risk, and that VG's scale positions it better to spread out the risk throughout their whole customer base.

One services manager noted that VT works very little at the moment with uptime guarantees, instead they offer compensation if a problem cannot be resolved within a certain time period. Where uptime guarantees have been attempted at dealer level, they require significant risk and responsibility from the supplier, with financial penalties if the commitment is not met. The respondent further explained that being able to deliver on these commitments would require agreeing with customers on sanctions, conditions, and responsibilities, and that is significant contractual work that is not yet fully developed. A sales manager further highlighted that the mining environment makes this even harder, as service contracts for this type of tough operations are already very expensive because repair and maintenance costs are high, with pricing built on historical failure data. The respondent also explained that this makes EaaS difficult as it represents a learning journey and that VT currently has very few cases to learn from. The balance sheet constraint adds a second dimension to this tension. As one respondent explained, scaling EaaS across VG volumes would require placing large amounts of locked capital on the balance sheet, probably resulting in concerns from the capital markets and investors. Another respondent at VG further noted that it is financially heavy to carry BMs like EaaS, and questioned whether it can be defended from a financing perspective.

4.3 Organizational Reconfiguration as the Enabling Condition for BMI in Mining

This section shows that realizing the BMI potential described in the previous section is not only a matter of developing the right offerings. It also requires changes within VG's own organization. Respondents from VG pointed out that to achieve successful BMI in a mining context, it is important to align the organization across its business units, and to close competence gaps.

4.3.1 Building Pricing Competence Under Operational Uncertainty

Pricing service contracts and new BMs for BEV in the mining context exposes a significant challenge. Respondents from VT explain that they have accumulated years of experience in offering km-based pricing of service contracts for conventional road-transport and have therefore gained substantial knowledge in this area. However, the mining business is driven by hours and tonnes hauled rather than distance driven, an area where several respondents acknowledged the need to build new and more comprehensive knowledge. Historic usage data is the primary means for developing accurate pricing arrangements. This process is complicated because of the heterogeneity of mining sites and applications. Service contracts are tailored accordingly, which requires detailed information about the operating environment for accurate pricing. Without ongoing follow-up with the customer to monitor actual conditions, service contracts risk becoming more expensive than they need to be.

With BEV technology, there is an additional challenge in including battery degradation in the pricing. Lack of knowledge in cycle aging and lifetime of batteries increases the risk of replacing batteries before the truck's end of life. One VT respondent noted that including battery replacement in service contracts adds to the price and therefore customers sometimes defer the coverage. In arrangements involving battery replacement, VT guarantees a minimum usable energy level during the contract period, and the battery is switched if that cannot be upheld. Historical repair data normally anchor pricing, but for BEV these data points are not as reliable as for ICE because of the still immature technology.

For entirely new service models with no existing reference points, the problem is more fundamental. Customers need to be convinced of the value these models create, which can require long and tedious negotiations that make both sides dissatisfied. One VT respondent argued that some arrangements might have to be tested for free to get traction and gain approval. The value creation question is central in deciding how to price an offer. Pricing of EaaS introduces additional variables such as the value perceived by the customers of not having assets on their balance sheet. Currently, EaaS pricing for VCE is calculated by determining ownership plus operating cost for customer and then assign a usage-based hourly flat fee for this. However, as a baseline, VCE needs to have its own key metrics covered. VT on the other hand uses a tiered pricing with a higher hourly cost for the initial hours used and with a gradual decrease in price with more hours.

Another parameter to consider is how risks should be distributed between VT and the customer. For contracts where VT assumes more risk, it must be compensated for it. Delivering on uptime commitments requires VT to develop a deeper understanding of both the exact costs of service and repairs and the specific operating conditions at each customer site. One VT respondent pointed out "There is a gap between what Volvo can deliver on uptime and what customers expect, as well as what customers are willing to pay for it". As previously mentioned, VT currently works with offering compensation if a problem cannot be resolved during a set time-interval instead of guaranteeing uptime. For uptime guarantees to work in practice, negotiations around what each party is responsible for need to be agreed upon. Furthermore, if VT were to own the uptime arrangement, VT needs to secure the supply chain for a steady flow of spare parts, and in some cases spare trucks. More data would also be needed to monitor usage and for predictive maintenance to be possible. It would also require VT to have dedicated service and technical personnel on site or in close proximity at all times to achieve timely and accurate servicing.

4.3.2 Aligning Product, Service and BM Development Cycles

While services can help reach additional revenue streams and improve the total offer, a senior strategy executive argued that VG remains fundamentally an equipment supplier, producing products rather than services. However, as section 4.2 showed, there is a strategic drive and effort to incorporate more services to create a more holistic total offer to increase value creation. A strategy manager at VG argued that new competition from integrators that bundle solutions from different providers to the end customer creates an imperative for VG to strengthen its total offer to minimize the risk of becoming a commodity. Therefore, VG faces pressure to strengthen its service development capabilities. A respondent noted that the problem with service development is that it sometimes is slower than product development due to competition for resources, and because the enabling technology required for services sometimes does not yet exist. Respondents within VG argued that there are efforts to balance development using organizational arrangements and governance, but they still favor product development.

Even where total offer solutions are developed, there is a risk for product and services being developed in isolation. Siloed development creates misalignment regarding how services should complement the product. A detailed service plan is needed to understand which product functionalities are needed to support a specific service. A core structural challenge is that product and service development often operate on different cycle times, making simultaneous release of complementary functionalities difficult to coordinate. BM development is currently separated from both product and service planning, though VCE has piloted approaches that incorporate feedback from BM development into existing product and service plans. Aligning these development priorities aids in simultaneous release of complementary functionalities. In VT's transition towards more service-oriented offerings, costs that previously fell to the customer now land on VT, which puts new requirements on the product.

New BMs could also introduce cultural tensions that must be actively managed. New commercial arrangements clash with existing organizational structures built around product sales, and new structures depend on existing ones that compete for the same resources. A senior strategy executive described the need for change management that helps internal stakeholders understand why change is necessary and what it requires of them.

4.3.3 Cross-Unit Integration as a Precondition for Total-Offer Delivery

VG delivers several products needed for the mining industry's core operations and therefore possesses significant cross-bundling opportunities across its business units. The possibility of procuring an integrated offer from VG, for instance combining both trucks and wheel loaders in the same arrangement, is something BC expressed interest in. Currently, there is no dedicated mining division within VG, instead the company works cross-functionally utilizing vertical expertise that is distributed across organizational boundaries. Therefore, realizing the cross-bundling potential, one fleet manager argued, requires strong organizational coordination. While one senior sales executive stated that VT works together with VCE to electrify mining operations, opportunities for even further collaboration exist. The different business units of the company have different dealer networks and brand footprints which require further integration to deliver a bundled offer consistently.

Aligning business units is a necessary step to facilitate better collaboration within the organization. One mechanism for achieving this is through shared goals. One service manager argued that common KPIs across organizational boundaries are crucial to managing internal tensions. Even if such KPIs might be hard to implement, they can have a significant effect on alignment. One senior strategy executive highlighted that rotation between internal and external facing parts of the organization help facilitate knowledge sharing and alignment between divisions. The respondent further argued that involving executive levels in market and customer contact can have positive bridging effects, but it is important not to take over market dialogues.

Since what represents a commercially significant volume for one business unit may be marginal for another, ensuring that low-volume segments like mining receive appropriate prioritization across the business units requires deliberate governance. Furthermore, several respondents stated that achieving the scale needed for cost-effective development and service delivery is challenging, which affects the overall profitability of serving mining customers. Despite this, a senior strategy executive argued that it is still critical to stay in the mining industry to not lose market share in an important segment, meaning that sufficient steady investments are needed.

Even though VT has the primary customer contact, the EaaS solution for VT is currently developed and driven by VFS, which has the financial capacity to hold assets on their balance sheet. This structure requires that profits are distributed fairly between the business units, attributing revenue where it originates. The EaaS model also fundamentally changes the revenue stream. VT goes from receiving revenue during the initial transaction, to earnings over the asset lifetime, which places new demand on financial planning and stability.

As previously mentioned, customers want charging solutions included in the total offer, which is also a priority for VT. One respondent from VE argued that their goal is for VT not to lose a sale due to absence of appropriate charging solution in place. This rationale, using charging solutions as a driver for BEV sales, is what motivated VG to create a separate business unit, with its own dedicated resources. The same respondent argued that if this would have been developed internally within VG, it would have faced considerable risk of being deprioritized while competing with other projects. However, the respondent argued that further work remains to fully reach the potential of this collaboration.

4.3.4 Redesigning the Sales Process as an Enabler of Deeper Value Creation and Capture in Mining

The move towards more service-oriented arrangements places entirely new demands on the sales process regarding how to reach the customer with the BEV offer. These arrangements typically entail higher upfront costs, which are most visible to procurement decision-makers, yet the TCO for the customer organization may be lower when service and operational expenses are accounted for. Respondents with close customer contact argued that convincing customers to accept new service-based arrangements requires broader organizational involvement from the customer side, including accounting or financial staff who can help evaluate and communicate the business case internally. One fleet manager argued that involving the customer's financing department in the procurement process can help motivate EaaS solutions by demonstrating the value of keeping the asset off the balance sheet. Overall, there is a clear need to help customers understand the value that service solutions create beyond the initial transaction.

Developing these solutions requires a deeper relationship with the customer to enable richer value creation. Data sharing has mutual benefits for VT and BC: VT develops a better understanding of how their vehicles are used in the operations, allowing for products and services better tailored to customer needs and BC gains insight into VT's product roadmap, supporting its own BEV acquisition planning. Respondents from BC expressed a need for support with simulations to see what VT actually can deliver in terms of the product, alongside guarantees and services included in the offer. BC also sees it as a necessity to test VT's product in their operations, promoting piloting to understand the potential and limitations. Several respondents also argued that the number of steps between customer and product and service development need to be reduced, reducing the risk of misaligning what is developed and what is valued.

The sales process itself requires structural adaptation. A senior sales executive argued that selling BEV requires substantially more effort than conventional truck sales, without a corresponding increase in compensation. The current sales incentive structure needs to be reconfigured to favor BEV, despite lower sales volume for the same amount of work, to convince the sales personnel to focus on selling BEV. Beyond the incentive structure, sales personnel need to construct and communicate a compelling business case for using BEV in their operations, which requires operational and financial data that the customer sometimes does not have readily available. The sales strategy needs to shift toward higher level of integration with the customer, adopting a solution-oriented selling approach. The sale of BEV with surrounding services increases the complexity of the sale, creating an imperative for a detailed understanding of the customers' operation and what needs that should be fulfilled.

Being first with new offers can also improve the sales process. VCE saw a clear upside of being the first to offer EaaS to their customers, allowing them to establish a reference point for how such arrangements should be constructed commercially. Respondents from VCE argued that mining customers have particularly high demands on uptime and productivity guarantees, requiring a solution perspective rather than a product perspective. This means the sales process must address how the total offer enables the customer to achieve required capacity and uptime, allowing them to focus on core extraction activities rather than managing truck performance.

5

Discussion

5.1 The Underground Mining Context as an Amplifier of Known Barriers and a Source of New Ones

The barriers to BEV adoption that are identified in this study broadly confirm the barriers already established in prior literature. At the same time, the findings reveal that the mining context amplifies their severity and introduces barriers that existing research does not fully capture. The findings align with the framework presented by Sugihara et al. (2023) with their categories of economic, technological, and social barriers. The high upfront cost of BEV, uncertainty about its residual value, an unfavorable TCO over the BEV's lifetime, and high upfront investments in charging infrastructure correspond to the economic category. Range limitations, durability, charging time, and payload reduction with BEV are all related to the technological category. Social barriers are less prominent but exist in terms of new servicing competencies needed, and internal tensions between strategic and operational priorities within the mining organization. The findings also align with broader adoption literature in that adoption costs extend beyond the technology itself. Investments in charging infrastructure, training of new servicing competencies, and replacement of complementary equipment all contribute to the economic barrier (Hall & Khan, 2003).

However, the extent to which these barriers appear in underground mining is not fully explained in the literature. Ediriweera & Wiewiora (2021) and Assimi et al. (2023) identify the mining industry's capital intensity, short-term production focus, and risk aversion as preconditions that make technology transitions particularly difficult. The findings support this framing and extend it even further. The productivity imperative that emerged across several respondents does not simply function as one barrier that is equal to all others, it acts as an amplifying condition that intensifies every other barrier. This is also the reason that it does not fit cleanly into any single category of Sugihara et al. (2023), as it contains aspects of all three categories simultaneously. Any technology that results in even marginal downtime or productivity risk is treated as operationally unacceptable even if it has other beneficial environmental or financial aspects. This is in line with Macdonald et al.'s (2016) argument that the perception of value is judged differently at the strategic and operational levels. Executive managers may pursue adoption of new technology for strategic and sustainability reasons, and operational and sourcing managers evaluate the technology solely on whether it will reliably deliver the required output. This internal tension in evaluation means that even strategically committed mining companies can face internal resistance that could stall the adoption at the operational level.

The findings further reveal barriers surrounding the infrastructure conditions that are created by the underground environment itself. Prior research frames the infrastructure challenges of BEV adoption primarily as a capital expenditure. However, this case reveals something more fundamental where the underground mining environment creates a set of compounding infrastructure conditions that in combination hinder the adoption and limits the supplier's ability to respond to it. These conditions reflect the compatibility barrier stated by Rogers (1983). The BEV's infrastructure requirements are not aligned with the existing technical and physical systems within which the mining operation currently operates. Furthermore, the grid upgrades that are required for large-scale BEV charging depend on utility companies and regulatory processes that neither the mining company nor VT can influence in major ways. This creates a dependency on actors with no aligned commercial plan or timeline. This dependency illustrates the environmental element from the TOE framework (Baker, 2012). External factors such as regulatory processes and utility infrastructure can have a substantial effect on adoption. A further dimension of this infrastructure challenge concerns the strategic logic of BC regarding ownership. The findings show that BC wants to own the charging infrastructure rather than having it provided by a single supplier. The logic is to avoid lock-in effects. If a single supplier were to own and operate the charging infrastructure, that supplier would gain leverage over BC and limit their ability to switch suppliers or negotiate terms. This means that even if VT in theory could resolve parts of the infrastructure barrier through bundling, the customer could resist such an arrangement for reasons unrelated to cost or technical capability. This represents a limit on supplier BMI that is not explained in the literature. It is not only that the infrastructure is expensive or technically complex, but it is the customers' own strategic interest that prevents the supplier from owning the solution.

Poor underground connectivity is another barrier, which prevents real-time data collection from BEV in mining operations. The inability to monitor vehicle performance in real time underground means that VT cannot collect the operational data needed to confidently offer an adequate service level and uptime guarantee. Beyond connectivity, the battery safety risks represent a further dimension that is intensified by the underground environment. While Hooli & Halim (2025) identify the battery fire risk as a general concern for BEV, the underground environment makes such incidents much harder to manage than in surface applications. Furthermore, because mining trucks are in most cases not road-legal, servicing must be conducted on site, and sometimes in confined underground spaces requiring certified technicians, adding further complexity to maintaining adequate service levels. These conditions are not independent barriers, but are rather interconnected aspects of the same underlying challenge, where the underground environment limits both what customers can adopt and what suppliers can credibly offer in response. This suggests that the level of servitization in underground mining is largely determined by the physical environment in which the service must be delivered.

The relationship between supplier and customer in managing technology obsolescence risk is another distinct finding. This concern is related to the economic category of Sugihara et al. (2023), but differs from a simple cost barrier in that it is also driven by uncertainty about future technological advancements, rather than current pricing. Investing capital in current BEV generations creates a concern about having achieved full return on investment before the technology is superseded. This aligns with Hall & Khan's (2003) argument that for uncertain technology, such as the BEV, firms tend to delay adoption to avoid sunk costs. This is a concern that slows adoption at the very moment when sales volume is most needed to drive technology development forward. As VG respondents described, high sales volumes are required to achieve the pace of technology development that would reduce obsolescence risk, yet the volume depends on the customer adoption that the risk itself discourages. This creates a structural dilemma that neither the customer nor supplier can resolve independently. What makes this particularly relevant to the mining context is the combination of high per-unit costs and low overall sales volumes for suppliers. This nuance suggests that this structural logic remains a challenge that requires a more coordinated response from both sides of the supplier-customer relationship. BC respondents noted that the short operational life of 3-4 years for mining trucks partially mitigates the lock-in technology obsolescence risk of the vehicle itself. This does not, however, account for the broader infrastructure picture. The accompanying infrastructure represents a substantially larger and more long-lived commitment that cannot be replaced on the same cycle. This means that the true lock-in horizon extends well beyond the BEV itself, meaning that the obsolescence dilemma should be seen in a wider context rather than the vehicle replacement cycle alone.

5.2 Potential and Constraints of Servitization in the Mining Context

The adoption barriers described in the previous section all point toward a common underlying structural issue. The traditional transaction-based model of selling a truck is inadequate to address the operational, financial, and technological uncertainties that BEV adoption in underground mining faces. Beyond the barriers themselves, the heterogeneity of the mining customers further limits VT's response. This customer heterogeneity is not treated as a barrier in this study, since variation across customers does not prevent any individual customer from adopting BEV. It is rather treated as a constraint on the supplier BMI initiative where it limits how broadly a specific BM can scale. The findings show that VT's response to this has been a progressive movement along Tukker's (2004) PSS spectrum, where VT has moved from pure product-oriented transactions towards more use- and result-oriented service arrangements. This section highlights that this response is consistent with theory, but contains a structural contradiction that limits its effectiveness in practice. The contradiction is that the primary mechanism through which servitization creates value for the customer and absorbs the risks of BEV adoption, simultaneously undermines the economic case for adoption by driving up the cost of the offering. Understanding how this contradiction arises and why it is particularly relevant in the mining context, represents one of the central analytical contributions of this study.

The BMI initiatives identified in this chapter address the barriers discussed in 5.1 in different but related ways, with the productivity imperative acting as the amplifying condition that shapes them all. By offering the full coverage gold contract, VT aimed to resolve the service competency gap, utilizing its own technical expertise and absorbing the uptime responsibility from the customer. The specific infrastructure and integration burdens that BEV introduces, where coordination between charging, energy, and digital services would otherwise be the responsibility of the customer, have been addressed through the development of the total offer. The introduction of EaaS aims to resolve several identified barriers simultaneously by shifting the concerns around high upfront costs, residual value uncertainty, and technology obsolescence risk from the customer to VT. Piloting addresses the technological barriers indirectly, by creating a structured way to generate the operational data needed to better price service commitments, and to gain knowledge on how to deliver on them. The deliberate response to maintain a portfolio of BMs is because the barriers of adoption do not affect all mining customers equally, where financial and ownership preferences vary across them. While these mappings establish the connection between VT's BMI initiatives and the mining customers' adoption barriers, the central focus of this section is the structural contradiction that emerges when the mechanism designed to absorb risk drives the cost back up.

VT's movement along the PSS spectrum has been accelerated because the BEV itself made a standalone transaction commercially insufficient. As the findings in previous sections show, BEV's cost and technological complexity changed the terms on which customers engage with VT. Customers became less willing to carry operational and financial uncertainty themselves and instead expected the supplier to absorb more of it through packaged services. The introduction of the gold contract as the default for every BEV sale reflects this shift, marking a move from product-oriented services, where maintenance contracts simply accompany a product sale, toward a more integrated arrangement where VT assumes responsibility for performance, wear and uptime as part of its core offering. This aims to overcome the service competency barrier, while also addressing the uptime sensitivity that the productivity imperative creates around any service disruption. This is in line with Baines & Lightfoot's (2013) description of PSS as a shift in perceived value from the physical product to the delivered capability, where the product works as the primary enabler of value rather than the primary object of value. The development of EaaS represents this as an even further transition along the spectrum where it addresses multiple barriers simultaneously. These include removing the high upfront capital that acts as the primary economic barrier, as well as replacing unpredictable maintenance expenditure with a predictable usage-based cost structure. It also creates a mechanism for managing technology obsolescence risk by allowing newer truck generations to be rotated into the fleet as they become available. Taken together, the full coverage gold contract and EaaS represents a servitization trajectory in which VT progressively takes on more of the risk and responsibility that BEV adoption would otherwise place on the customer. This reflects Rachinger & Müller's (2024) observation that in electrification transitions, customers require more integrated solutions rather than fragmented offerings. In line with Teece's definition of BMI, these arrangements also require a reconfiguration of value delivery since the architecture, channels, and partnerships through which the value proposition reaches the customer have higher resource demands. The total offer concept makes this particularly relevant since delivering it depends on several of VG's business units functioning as a coordinated system rather than as independent actors.

EaaS within VCE originated as a direct response to a key customer requirement, and the commercial, legal, and operational foundations built together with that engagement were later reused as the model scaled. VT's own service development approach requires at least one customer to be in the loop before any initiative can begin. This is a logic that is in explicit contrast with product development, where concepts must be fully resolved before production starts. This pattern is consistent with Chesbrough's (2010) argument that BMI, when faced with uncertainty, requires experimentation rather than upfront design, and with Thomson et al.'s (2023) concept of BM piloting as a mechanism for managing technological and commercial uncertainty in industrial settings. In VT's case, piloting serves a dual purpose. It reduces the commercial risk of committing to an untested model at scale, while at the same time generating operational insights that make scaling possible in the first place. The advantages of this are two-sided, where the customers are, at an early stage, able to influence BM configurations, and always having the possibility to try out the newest technology under their own site-specific conditions. This bottom-up and customer-driven logic does, however, also carry a risk that the findings highlight. The solutions and designs of new BMs might become too niche and specifically designed for certain customers, that may result in scaling difficulty. Sjödin et al. (2020) argue that value creation and value capture in outcome-based models need to be developed together, yet the reactive, customer-pull mechanism through which VT's BMs have evolved makes this alignment structurally difficult to achieve.

The heterogeneity of the mining customers adds a further structural dimension. As the findings show, VT has responded to this heterogeneity not by committing to a single dominant BM but by maintaining a portfolio of arrangements simultaneously. This is consistent with Matthyssens & Vandenbempt's (2010) argument that servitization paths are not always linear or uniform, and that market characteristics lead different customers toward different positions in the PSS spectrum at the same time. What is theoretically significant about this finding is that it complicates the conventional servitization narrative, which tends to describe a progressive movement towards result- and outcome-oriented services as the supplier develops competence and confidence (Tukker, 2004). VT's case suggests that in contexts where customer heterogeneity is high and the technology is immature, the management of both configurations within a single BM and a portfolio of different BMs becomes a requirement rather than a temporary solution. A configuration refers to adjustments within a single BM with variations such as contract length or service level, while a portfolio consists of fundamentally different arrangements that differ in asset ownership and risk distribution. This has implications for how BMI should be conceptualized in a capital-intensive mining context, that rather than a trajectory toward a single advanced model, it may be better understood as the ongoing management of a portfolio of models with different configurations, each calibrated to customer segments with different barrier profiles and financial constraints.

The ownership preference pattern identified in the findings gives rise to another structural dimension to understanding why servitization faces specific constraints in the mining context. Tukker's (2004) PSS spectrum assumes a progressive willingness on the customer side to transfer ownership and operational responsibility to the supplier as arrangements become more advanced. The findings challenge this assumption in a mining-specific way as the customers' willingness to transfer control is not uniform across their assets. It is inversely related to how close the assets are to the core extraction activity in the mines. This means that the assets and operations that would theoretically generate the most value from result-oriented arrangements such as EaaS are precisely the ones that customers are least willing to transfer control over.

A very significant finding concerns the structural contradiction at the core of VT's servitization response. Mining customers want VT to carry the risks of BEV adoption, including the financial risk of high upfront investment, the operational risks of battery degradation as well as the residual value risk of an asset whose market value is uncertain. Yet the cost of pricing those risks into a service offering often pushes the total cost above what diesel currently costs, which is precisely the barrier the BM was designed to overcome. The contradiction therefore directly refers to the economic barrier. The mechanism that absorbs financial and operational risk on behalf of the customer simultaneously reintroduces the unfavorable TCO that motivated the BMI response in the first place. As one product manager at VT described, as-a-service models are frequently pushed at leadership level but often fail in implementation because when someone takes on more risk, they need to be compensated for it, and when the price goes up to cover that risk the TCO no longer holds. The solution does sometimes in other words reproduce the same problem it was originally designed to solve. It is, however, important to consider that, while the development of BMs is crucial for new technology adoption, the demand for BEV in mining has advanced ahead of the technology and economics to make it commercially viable. This results in less of a market pull for the BEV, and instead more of a technology and sustainability push originated from strategic and regulatory pressure.

This dynamic is in line with what Gebauer et al. (2005) identify as the service paradox. The paradox describes an effort where manufacturing companies invest heavily in extending their service abilities but fail to translate these investments into expected financial returns because the costs of delivering advanced services are systematically underestimated. Neely's (2008) large-scale findings, that servitized manufacturers generate lower profit margins than their pure product counterparts, suggests that this is not a singular failure, but a systematic risk of the transition. In VT's case, the paradox is further intensified by the mining specific conditions that make pricing risk particularly difficult. As the findings show, since BEV in underground mining applications is a relatively new phenomenon for VT, they also lack the historical operational data for BEV that would normally anchor service contract pricing. The battery degradation behavior under the extreme conditions of underground mining, including heavy loads, steep gradients, and high operational intensity is not well understood. Uptime commitments require not only contractual agreement but a supply chain that can deliver spare parts and service technicians to remote underground sites within agreed timeframes. Each of these conditions adds a risk premium that, when added up, can make the total offer financially unappealing to the customers who are most affected by the barriers it aims to address. The findings suggest that the pursuit of EaaS reflects a deliberate long-term positioning logic. By developing the foundations for EaaS now, even at the cost of short-term underperformance, VT builds the capabilities and customer relationships that will be required when the market matures and customer pull strengthens.

The consequences of this pricing challenge are visible across several dimensions of VT's current service provision. Rather than offering uptime guarantees, VT currently provides compensation when problems cannot be resolved within a set time interval. This is a structurally different commitment that reflects the difficulty of pricing and delivering on performance outcomes in the mining context. The contractual framework that is required to be able to offer uptime guarantees in practice, including defining responsibilities, sanctions, and operating conditions between parties, is still being developed. Findings suggest that demand for these advanced arrangements such as EaaS has not been fully established, precisely because the risk absorption that makes them attractive also drives up costs to the point where it is financially unviable. Kastalli & Van Looy (2013) describe this as a clash between the standardization logic of manufacturing culture and the heterogeneity and flexibility required for advanced service provision. This tension is clearly visible in the mismatch between VT's established general km-based pricing expertise and the hour-based, site-specific, battery-degradation-inclusive pricing that usage of BEV in the mining industry requires. This could be viewed as a capability gap within VT that reinforces Parida et al.'s (2014) argument that firms which extend services without developing the underlying organizational capabilities are likely to experience negative rather than positive financial outcomes. It is however important to note that this represents a resolvable organizational problem rather than a fundamental market failure. While some customers might not justify the increased cost of risk transfer, BC respondents explicitly confirmed willingness to pay for uptime guarantees and battery residual value commitments. This suggests that value-based pricing for risk transfer is in fact commercially viable in principle once VT develops the competence to price and deliver with precision. As previously noted, however, since the financial viability and technological feasibility of BEV in mining is not adequate, the ability to have the right pricing competence is still secondary.

5.3 Realizing BMI Through Organizational Reconfiguration

While the previous section establishes that servitization is the structural response to BEV adoption barriers, the fundamental contradiction limits its effectiveness in practice. This section argues that the contradiction is not primarily a design problem but rather an organizational one. Overcoming the adoption barriers requires BMI to be realized across all three of its dimensions. The findings reveal that VT's ability to realize the BMI potential is constrained by four interconnected organizational gaps. These include an underdeveloped pricing competence for mining specific service contracts, a misalignment between product and service planning cycles, insufficient coordination across business units, and a sales process that has not yet adapted to the demands of solution-based selling. Together, these gaps span all three dimensions of BMI, where alignment between product and service planning concerns value creation, cross-unit coordination and sales process adaptation concern value delivery, and pricing concerns value capture. Understanding how BMI overcomes barriers therefore depends not only on the mechanisms, but also on the organizational conditions under which those mechanisms can function as intended.

The service paradox's most direct organizational expression is VT's inexperience to price risk absorption adequately to make advanced service arrangements commercially viable for both parties. Reim et al. (2016) distinguish between three categories of operational risk that PSS providers must manage. All three are present in VT's current situation where delivery competence risk is visible in VT's current practice of offering compensation for unresolved problems rather than uptime guarantees. This reflects the difficulty of reliable service at remote underground sites within market demand timeframes. Technical risk is compounded by the absence of historical BEV failure data for underground mining applications and the unknown battery degradation behavior under extreme duty cycles. Behavior risk is seen in the absence of standardized contractual frameworks for defining responsibilities, sanctions, and operating conditions between VT and mining customers. This reflects the commercial immaturity of BEV in underground mining at sufficient scale.

The pricing gap connects directly to a deeper structural misalignment between how VT develops products, services, and BMs. Sjödin et al. (2020) argue that value creation and value capture in outcome-based BMs must be developed in parallel. From the start, what is offered and how much it costs need to be coordinated, not put in sequence. The findings show that this alignment could be structurally difficult to achieve since product development and service development processes operate on different cycle times and compete for the same organizational resources. This is not unique to VT, and Kastalli & Van Looy (2013) identify that this is a common phenomenon within manufacturing firms as they navigate the servitization transition, driven by deeply embedded cultures of standardization and efficiency that sometimes clash with the flexibility that advanced services require. The consequence in VT's case is that services are designed around products whose functionalities are already fixed, and BMs are developed without full visibility of what the product and service combination can actually deliver. This is in line with what Broekhuizen et al. (2018) identify as one of the central strategic trade-offs in BMI implementation. New BMs require a degree of independence from existing organizational logic to develop freely, yet they simultaneously depend on existing product and service ability to be deliverable.

As discussed, delivering the total offer requires all of VG's relevant business units to function as a coordinated system. The findings show that collaboration across these units already exists: VFS provides the financial architecture that makes bundled arrangements like EaaS commercially viable for VT, VE was established as a dedicated entity to develop charging solutions for the BEV to complement the total offer, and VCE's experience with EaaS provides commercial and operational foundations that VT is actively drawing on. This is in line with what Rachinger & Müller (2024) argue that with transitioning towards electrification, the value delivery becomes increasingly dependent on structured coordination between interdependent actors. Without the right alignment, offers risk becoming fragmented which customers experience directly. The findings suggest that there is an awareness of this within VT, particularly that shared governance mechanisms, common priorities of the mining segment, and clearer profit distribution between units all require further development. This would strengthen the total offer and unlock cross-bundling opportunities that mining customers, including BC, have explicitly expressed interest in. However, VG's decision to position itself as an integrator rather than owning the complete solution introduces a dependency on external partners whose priorities and timelines are not always aligned with VG's.

To be able to reach customers more successfully, the organizational dimension regarding the sales process needs to be adapted to the demands of solution-based selling. Kowalkowski et al. (2015) argue that the transition to servitized offerings requires manufacturers to fundamentally rethink how they engage customers. Suppliers need to move from product-oriented transactional interactions to deeper relationships in which the supplier develops genuine understanding of customer operations. Selling a BEV with surrounding services requires substantially more effort than a diesel truck sale. It involves a broader set of customer stakeholders than traditional procurement interactions involve. EaaS offers a distinct financial appeal where it keeps the asset off the customers' balance sheet and replaces uncertain variable maintenance expenditure with a predictable usage based cost structure. However, this is a value that is expressed more in accounting terms, which by itself is not always convincing for procurement decision-makers. Consequently, suppliers need to be able to reach multiple organizational levels on the customer side, each with different priorities and evaluation criteria. However, the current sales incentive structure does not adequately compensate for this additional complexity, therefore creating a misalignment between what solution selling requires and what VT currently rewards. Guerin (2020) draws upon these conclusions that mining customers are significantly more willing to engage deeply with suppliers who demonstrate genuine understanding of their operations, suggesting that resolving the sales process gap is not only an internal organizational matter, but a precondition for the kind of customer relationship that advanced service arrangements require.

These findings suggest an important nuance regarding the sequencing of BMI in capital intensive industrial contexts. Biloshapka & Osiyevskyy (2018) note that value delivery is frequently left out in the BMI literature and often treated as being included in value creation and value capture. The findings of this study suggest that in the context where technology is immature and operational uncertainty is high, the value delivery demands specific and focused attention alongside the other two dimensions. While Teece's (2010) framework positions value creation, delivery, and capture as concurrent and interconnected, the VT case shows that VT's pricing capabilities, cross-unit governance, and sales process adaptation have not kept pace with the ambition of the BM itself. It should, however, be noted that these organizational gaps only become the binding constraint once the underlying technology reaches adequate commercial viability. This suggests that for equipment suppliers in similar positions, value delivery in particular should be given equal importance alongside value creation and capture rather than being left to follow them. The organizational work required to deliver outcome-based offerings is what determines whether these types of BMs can actually function.

The stakes of failing to close these gaps are major. Reim et al. (2016) argue that when PSS risks cannot be managed in a sustainable way, the typical organizational response is risk avoidance and possibly withdrawing from advanced service commitments. Kowalkowski et al. (2017) identify this as a primary driver of deservitization, where firms cannot overcome the organizational barriers to advanced service provision, and instead retreat toward simpler product-offerings. VT's current position, where EaaS demand has not yet been fully established and the contractual infrastructure for outcome-based arrangements is still developing, places it at a juncture where both trajectories remain open. The organizational transformation that is described in this section is therefore not only a solution for realizing BMI potential, but a fundamental precondition for avoiding a retreat that would leave the adoption barriers of BEV unaddressed.

6
Conclusions

6.1 Adoption Barriers in Underground Mining Compound Rather Than Accumulate

The findings from this study suggest that the BEV adoption barriers in the mining industry confirm the existing literature regarding BEV adoption, while the underground operational environment presents a unique context that amplifies their severity and introduces new obstacles. The contribution of this study is therefore not the identification of entirely new barrier categories, but rather the demonstration that in the underground mining context, these barriers interact with each other and compound in ways that are qualitatively different from other BEV application contexts. Importantly, the underground environment not only constrains what customers are able to adopt, but simultaneously constrains what suppliers can credibly offer.

The high productivity demand in the mining industry represents a significant barrier to adopting new technology that also amplifies all other barriers. While all investments are evaluated on a financial basis, a loss in productivity has a significantly higher impact than additional expenditure in equipment. Downtime of a truck directly results in a stopped production cycle, translating into substantial revenue loss. This makes mining operations less tolerant of productivity uncertainty compared to other industries where equipment underperformance can be more easily absorbed by operations. Therefore, regardless of the strategic merit, if the BEV cannot compete with the ICE, full-scale adoption is not viable.

Infrastructure challenges are not unique to the mining industry and generally large industry sites across several sectors require significant grid upgrades and regulatory navigation. What the underground mining context adds is that it further intensifies the complexity. The physical installation of charging infrastructure deep underground, combined with the fact that the mining sites themselves often operate in remote locations where the grid capacity is limited, means that the infrastructure barrier is significantly more complex than in other settings. This makes it both harder to resolve and more dependent on external actors and regulatory processes outside the direct influence of either the supplier or the mining customer. Furthermore, poor grid connectivity limits the ability to collect operational data needed to evaluate the BEV performance in underground mining, which increases the difficulty both of operating new technology and of developing new products and services needed to support adoption.

Together, these findings suggest that the pace and extent of BEV adoption in underground mining are not determined by any single barrier, but by the interaction between technological immaturity, operational conservatism, and a harsh physical environment that limits both ends of the supplier-customer relationship simultaneously. Because these barriers reinforce each other, addressing any one in isolation leaves the others intact. This compounded nature of barriers means that no single product improvement or commercial innovation is sufficient.

6.2 Servitization as a Necessary but Self-Limiting Response to BEV Adoption Barriers

This study finds that the primary form of BMI enacted by VT to overcome BEV adoption barriers is through servitization. The risk premiums required to make advanced service arrangements commercially viable for VT can, however, simultaneously increase the economic barrier they are designed to overcome.

Mining customers are increasingly keen on distributing the financial and operational risks of adopting new technologies with their suppliers. In response, VT has progressively reconfigured its value creation process by incorporating more features in their value propositions. By creating a more holistic total offer, the organizational complexity of adopting BEV is reduced, allowing mining customers to focus on core operations. The development of as-a-service models (EaaS) is a direct example of this transition. Notably, EaaS and other initiatives for BMI at VT showcase a high degree of customer centricity through active piloting and iterative customer involvement, something that is highlighted in the literature. However, this new approach to create value for customers also results in difficulties in capturing that value. Developing these two in an integrated manner was argued by theory to be important for maintaining and developing successful BMs. The shift from kilometer-based to hour- or tonnage-based pricing reflects a substantial challenge in VT's pricing competence. Consequently, this represents a central constraint in the value capture process for more servitized arrangements.

Another constraint of servitization emerges from the customer ownership preferences, where the findings show that mining customers in some cases actively resist supplier ownership and control of both charging infrastructure and certain assets. Customers want to own the infrastructure to avoid lock-in effects. Therefore, even if VT could theoretically resolve infrastructure barriers through bundling and a more complete total offer, the customer's own strategic logic prevents it. Adding to this, the closer a truck is to the core extraction activity of the mine, the stronger the customer's preference to maintain full ownership and control. This means that the most advanced servitized solutions such as EaaS can be the least sought-after solution precisely where the adoption barriers are the most intense.

A particularly significant finding is the evidence of the service paradox in this con-

text. When VT absorbs the financial and operational risk through advanced service arrangements, VT is forced to charge a risk premium. This is further complicated by the fact that with immature technology and the lack of historical operational data, the suppliers tend to price the risk absorption higher than may be necessary, which further intensifies the paradox. However, this is not always accepted by customers, especially since the BEV is already more expensive than the ICE alternative. This mismatch requires the supplier to engage multiple levels of the customer organization. The financial benefits of more advanced servitized arrangements, that could yield concrete uptime guarantees and sometimes keeping the assets off the balance sheet, are not always visible to procurement decision makers alone, which traditionally tend to evaluate against the upfront purchase price.
Even though more servitized models demonstrate potential benefits for the mining customers, not all customers have the same preferences. The mining customer base is too heterogeneous for any single BM or configuration of a BM to accommodate, partly because of the differences in capital structures, balance sheet constraints and risk preferences. Therefore, maintaining a deliberate portfolio of BMs, as well as the ability to configure individual arrangements to specific customers, is essential for meeting the needs of a diverse customer segment. This extends the conventional servitization narrative, which typically describes a progressive movement toward outcome-based models, suggesting instead that managing a portfolio is a strategic requirement rather than a transitional state. This also implies a dual organizational requirement for both the ability to standardize and scale across the portfolio, while simultaneously maintaining the flexibility to configure individual arrangements to specific customer needs. These demands are in tension with each other, and managing those tensions is a strategic challenge that is as important as the BM design itself.

In summary, the commercial relationship between VT and mining customers is driven by two separate but potentially aligned interests. VT seeks to grow revenue through deeper equipment and service arrangements, while mining customers seek to maximize ore production at minimum cost and risk. Servitization represents VT's primary attempt to bridge the gap between these interests by absorbing more of the customers' operational risk in exchange for increased revenue through more complete service contracts, retained spare parts revenue, customer loyalty, and a deeper customer relationship over time. However, the risk premiums required to make servitization commercially viable for VT can simultaneously price out the specific customers it was designed to attract. The mechanism intended to align the two interests can instead reproduce and widen the gap between them. Together these findings suggest that servitization is the strategic path through which VT attempts to overcome BEV adoption barriers, but it is constrained by both customer ownership preferences and the structural nature of the service paradox. Hence, closing the organizational gaps in pricing competence, cross-unit coordination and sales process adaptation is not only internal improvement priorities but preconditions for servitization to function as intended.

6.3 Further Research

Several areas of future studies emerge from the limitations and findings of this study. Future research could expand on the customer side of this case study and include a wider range of mining customers that differ in maturity, size and electrification commitment. Future research could also adopt more of an ecosystem perspective by examining how the broader network of actors involved in BEV adoption shapes the conditions under which servitization can succeed. This is especially relevant since the findings show that VT's ability to deliver a total offer is partly dependent on external partners whose priorities and timelines are not always aligned.

Since this study identifies and contextualizes BEV adoption barriers but cannot quantify their relative importance, future research could expand on this by quantifying which barriers are most prevalent, thereby allowing for more precise conclusions regarding how suppliers like VT should prioritize their BMI efforts.

This study is limited to the Swedish market, which has a specific regulatory environment and energy pricing structures that have certain implications for BEV adoption. Replicating this study in other geographies with higher electricity prices, weaker environmental regulations or less developed charging infrastructure would help establish which findings are context-dependent and which are universal across markets.

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Interview Guide

Volvo Group

Introduction

- Start by telling us about your role and what you work with.

Electrification

- How does Volvo approach electrification of the mining industry? What are the major drivers?
- Can you tell us about feedback you have gotten so far regarding electrification of mining?

Barriers

- What barriers do customers cite for not choosing BEV?
- Which barriers are hardest to address?
- Does the introduction of new technology affect your product or business model strategy?
- What barriers do you as an equipment supplier face when offering BEV?

Business model

- How do you approach development of new business models for new products like BEV?
- Who owns the BMI process and how does it tie together with product- and commercial- decisions?
- What challenges do you face when implementing new BMs?
- How do you decide what to include in the offering of BEV?
- How do you make sure that new BM initiatives actually are implemented and not just stays on a strategic level?
- How do you work with external partners to develop new offerings to create a more complete solution for mining customers?
- Walk me through what happens after a customer decides to adopt BEV
  - What does Volvo do to ensure they actually get the value you've promised?
- How would you describe Volvo's relationships with mining customers?
- For more service-intensive models, what would you need to do differently in terms of delivery compared to a more traditional sale?

- How do you approach pricing and revenue model design for BEV in mining
  - How is it different from products in the past?
- What different ownership or service models are you exploring for BEV in mining?
- What insights / feedback from customers have you gotten regarding what type of revenue model / ownership model they prefer?

Bedrock Co

Introduction

- Start by telling us about your role and what you work with?

Electrification

- How is Bedrock Co approaching the electrification of mining, specifically BEV?
- What motivates the adoption of BEV?
- How is BEV currently used in your operations?
- Where do you see potential to use electric trucks in your mining operations? Where do you not?
- What challenges in transitioning to BEV would you want a supplier to help solve, and what would you rather tackle internally?

Barriers

- What is holding you back from adopting BEV at large scale?
- How do you evaluate if an investment, for instance BEV, is financially sound?
- How do you think BEV would affect you day-to-day mining operations?
- Do you see any constraints with BEV compared to ICE?
- Have you found any internal resistance to the transition?

Business models

- What do you think is important to be included in the BEV offering?
- What additional services would be needed to increase adoption of BEV?
- After the trucks are delivered and operating, what kind of relationship would you want with the supplier?
- How does the relationship look like between the equipment supplier of BEV and you as a customer? What support would you need from a supplier during the transition to BEV?
- How would you prefer to pay for BEV
  - What payment structure would work best for your organization?

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

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