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Effects of material master data management on supply chain performance at FLSmidth: the moderating role of PiLog external service provider

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Abstract: In the dynamic landscape of industrial operations, the effective management of material master data within the supply chain is paramount for organizational success. This study investigates the challenges and solutions associated with Material Master Data Management (MMDM) at FLSmidth (FLS), a leading supplier in the cement and mining sectors. FLS operates within a complex and diverse supply chain environment, serving global clientele across various sectors. The study aims to understand the impact of MMDM implementation on supply chain performance at FLS, specifically focusing on performance metrics such as inventory turnover, order fulfillment accuracy, and lead time reduction. The moderating role of PiLog, an External Service Provider (ESP), is explored in this context. Employing a mono-qualitative approach, the study delves into MMDM implementation through in-depth interviews with 18 FLS employees and 4 PiLog customers. Thematic analysis reveals that well-implemented MMDM systems enhance visibility, planning, and inventory management, leading to improvements in supply chain performance. Challenges in stakeholder persuasion and infrastructure access are identified as common implementation hurdles. PiLog emerges as a crucial moderator, providing structured frameworks, emphasizing standardization, and addressing governance challenges. The findings underscore the importance of strategic partnerships between organizations and ESPs in successfully implementing and sustaining MMDM initiatives. Recommendations include strategies for overcoming infrastructure challenges, leveraging ESP expertise, and aligning with best practices in standardization and governance. This study contributes to the academic discourse on MMDM implementation and offers practical insights for organizations seeking to enhance supply chain performance through meticulous MMDM practices.

1 Introduction

In industrial operations, the management of material flows, information flows, and financial flows within the supply chain is the foundation of organizational triumph, ensuring a smooth flow of materials, information, and services from suppliers to end-users in enhancing value addition [1]. Supply chain performance (SCP) refers to how effectively and efficiently a supply chain achieves its goals, including metrics such as inventory turnover, order fulfillment accuracy, and lead time reduction. The Resource-Based View (RBV) theory emphasizes that organizations can achieve superior competitive advantages by effectively managing their internal resources, including material master data (MMDM), alongside their capabilities and competencies [2]. Material master data (MMDM) consists of critical information related to materials, such as specifications, inventory levels, and procurement details, which are essential for smooth supply chain operations and overall performance. FLSmidth (FLS), a prominent supplier offering engineering, equipment, and services to the global cement and mining sectors, operates within a notably intricate and diverse supply chain environment [3]. Given its expansive operations and extensive range of industrial products and services, including centrifugation, classification, crushing, filtration, and milling, the RBV theory underscores MMDM as a crucial resource for maintaining supply chain performance and enhancing overall operational performance, thereby reinforcing FLS's competitive advantage [4].

Inconsistencies or inefficiencies in MMDM can disrupt procurement, production, and distribution activities, impacting organizational performance [5]. The lack of integrated MMDM practices due to historical mergers and acquisitions has led to fragmented product information management, disrupting procurement, production, and distribution activities. This disarray manifests in duplicate data records, increased risk of fraud, suboptimal inventory

control, and reduced operational efficiency, particularly in FLS's logistics operations. However, a critical challenge underlying this complexity is the efficient management of material master data (MMDM). The relevance of MMDM is underscored by the challenges FLS faces in harmonizing material master data across its global operations. From an RBV perspective, the fragmentation of MMDM due to historical mergers and acquisitions represents a missed opportunity to leverage this strategic resource effectively, leading to inefficiencies in procurement, production, and distribution activities [6].

This study addresses the critical challenge of managing MMDM within FLS's complex supply chain**.** The absence of a unified MMDM framework at FLSmidth has led to significant inefficiencies in supply chain performance, negatively impacting the company's competitive edge in the global market. By applying the RBV framework, this research explores how MMDM can be optimized to strengthen FLS's internal capabilities, resulting in enhanced supply chain performance and sustained competitive advantage. The theoretical contribution of this study lies in its application of the RBV theory to MMDM within a complex industrial setting like FLSmidth, filling a gap in the literature on how strategic internal resources, such as MMDM, can be harnessed to improve supply chain performance. Practically, it guides the implementation of MMDM practices that align with FLS's broader organizational goals, ensuring that the company remains competitive in the global market. This study also extends the RBV theory by illustrating how external service providers, like PiLog, can moderate the relationship between internal resources and competitive advantage, thereby offering a more comprehensive understanding of how organizations can optimize their resource management strategies.

Organizations must diligently monitor and evaluate their integration strategies to ensure effectiveness and maximize their benefits [7]. Firms must focus on developing innovative manufacturing models and accessing capabilities for managing new technologies to enhance value creation, including financial management aspects such as cost and profit [8]. The emphasis creates the necessity of this broad and deep understanding to gain economic benefits within the logistics chain [9].

Consequently, the supply chain performance within FLS are marred by inefficiencies stemming from poor material master data management. Duplicate data records, increased risk of fraud, suboptimal inventory control, and reduced operational efficiency have become common challenges in logistics. The complexity of logistics increases the risks faced by enterprises, exposing them to various challenges such as natural disasters, geopolitical tensions, operational issues, and cybersecurity threats. This highlights the urgent need for stability and reliability across all levels of logistics. To achieve this, a comprehensive framework is essential for identifying, assessing, and mitigating risks, with a focus on proactive strategies to address potential disruptions and reduce their impact [10]. These challenges not only affect profits but also diminish customer satisfaction and loyalty in the context of market competitiveness [11]. From this standpoint, these processes necessitate enhanced logistics service management alongside an integrated approach, merging process integration for assessing satisfaction and identifying potential risks that could hinder the delivery of satisfactory logistics services. In this complex scenario, the importance of thoroughly understanding (MMDM) implementation and its influence on supply chain performance applied in logistics becomes a crucial concern.

This urges the investigation of efficient solutions to improve FLS's supply chain efficiency and overall operational effectiveness. Therefore to improve supply chain performance, companies should implement sustainable methods that reduce logistics expenses while increasing financial returns, specifically by decreasing lead times and boosting inventory turnover. This approach will significantly enhance the profitability of firms [12].

Implementing robust MMDM practices is akin to administering a precise remedy to the challenges faced by organizations like FLSmidth (FLS) in their supply chain performance. A well-coordinated MMDM strategy guarantees the uniformity, precision, and thoroughness of material master data, thereby addressing the inconsistencies and inefficiencies that disrupt supply chain operations [13]. By establishing clear naming conventions, such as standardizing the format for product codes, and codification standards, like adopting a universal coding system for materials, as well as data governance policies, which include regular audits and data validation procedures**,** help organizations harmonize their material master data across disparate systems. This fosters seamless communication and collaboration between various departments [14,15].

Automation of data cleaning processes and part description creation further eliminates manual errors, reducing delays and streamlining supply chain workflows. Through MMDM, organizations can optimize inventory management, enhance procurement accuracy, and minimize the risk of errors in production and distribution processes [16]. A comprehensive and accurate material master data repository is crucial for organizations to make informed decisions, enhance customer service, and secure a competitive advantage in a highly competitive market. In recent years, many organizations have increasingly focused on quality as a sustainable competitive strategy to stay ahead [17].

Globally, several approaches have been adopted to tackle material master data management challenges and enhance organizational supply chain performance by addressing the primary obstacles organizations face when integrating master data to achieve successful MDM adoption [18]. One prevalent approach involves the implementation of standardized data quality frameworks

such as ISO 8000. ISO 8000, the international data quality standard developed by organizations like PiLog, provides guidelines and best practices for data quality management, ensuring that material master data adheres to globally accepted standards [19]. By aligning with ISO 8000, organizations can establish a common language for data quality, enabling seamless data exchange and integration across supply chain partners. This standardization promotes interoperability, reduces data discrepancies, and fosters collaboration, thereby optimizing supply chain performance [20].

Moreover, use of technologies such as Machine Learning (ML) and Artificial Intelligence (AI) has revolutionized MMDM practices and acts as a transformative force, influencing diverse aspects of contemporary society by allowing systems to learn and evolve from data [21]. AI-powered algorithms can automatically cleanse, enrich, and classify material master data, detecting patterns and inconsistencies that might be missed by manual processes [22]. These technologies not only enhance data accuracy but also enable predictive analytics, allowing organizations to foresee demand patterns, optimize inventory levels, and enhance supplier relationships. Blockchain technology is another innovative solution that enhances transparency and traceability in the supply chain. By implementing Blockchain-based MMDM systems, organizations can create an immutable record of material master data transactions, ensuring data integrity and authenticity throughout the supply chain [23]. This heightened level of transparency reduces the risk of counterfeit products, enhances trust between supply chain partners, and improves overall supply chain performance. Blockchain-based models can provide a secure and transparent record of all supply chain transactions and activities. This transparency allows participants to identify potential issues and inefficiencies, minimize waste and delays, and enhance collaboration and communication [24].

Additionally, the adoption of cloud-based MMDM solutions has gained traction in recent years. Cloud platforms offer scalable and flexible MMDM services, allowing organizations to centralize their material master data in secure, easily accessible repositories and have emerged as an approach to improving the operations of manufacturing organizations [25]. Cloud-based MMDM systems facilitate real-time data updates, collaboration, and data sharing among geographically dispersed teams and supply chain partners [26]. The flexibility of these solutions enables organizations to adapt swiftly to changing market demands and scale their logistic operations without the constraints of traditional on-premise systems by facilitating the production flow of various items employed in discrete batch manufacturing processes, such as those found in the aerospace sector [27]. Cloud-based MMDM solutions enhance supply chain agility, enabling organizations to respond promptly to market trends, customer demands, and supply chain disruptions.

Moreover, fostering a culture of continuous improvement and data stewardship within organizations is integral to effective MMDM. Training human capital, suppliers, and other stakeholders on the importance of information management quality, governance, and compliance encourages proactive data management practices [28]. Defining the distinct contribution of logistics elements and responsibilities for data stewardship ensures consistent review, updates, and validation of material master data. Regular financial management audits and performance metrics enable organizations to gauge the efficacy of their MMDM initiatives, pinpoint areas for enhancement, and adapt strategies accordingly [29]. Encouraging a culture centered on information flow management and equipping individuals with the expertise and tools for proficient material master data management fosters sustained high logistic information quality. This approach optimizes supply chain performance, fostering enduring operational excellence.

Meanwhile, MMDM external service providers (ESPs), like PiLog, offer expertise in post-merger data harmonization. PiLog, a global provider established in 1978, specializes in data cleaning, classification, governance, and material criticality analysis. These providers offer specialized expertise and advanced tools tailored to the unique challenges faced by organizations like FLSmidth (FLS). By leveraging their knowledge and industry best practices, MMDM ESPs help establish robust frameworks aligned with international standards such as ISO 8000, ensuring that material master data is consistent, accurate, and compliant. For instance, PiLog, a reputable MMDM ESP, has developed tools and processes compliant with ISO 8000 standards, offering services like data cleaning, classification, and material criticality analysis [30].

Additionally, MMDM ESPs often provide sophisticated software solutions powered by AI and ML. These tools automate data cleaning, classification, and enrichment processes, enhancing the accuracy and completeness of material master data. Automation reduces manual errors, optimizes inventory levels, and improves demand forecasting, leading to more efficient material flow processes. Standardized data models, as advocated by ISO 8000, promote interoperability, reduce data discrepancies, and foster collaboration, enhancing supply chain efficiency and communication across international boundaries among logistics organizations [31].

Continuous support and maintenance provided by MMDM ESPs are instrumental in ensuring the longevity and effectiveness of MMDM implementations. Regular updates, training sessions, and consultations empower logistics organizations to adapt swiftly to market changes. This ongoing support ensures that supply chain performance remain agile and responsive to dynamic market demands, response to consumer needs enhancing overall operational efficiency [32,33]. However, organizations must carefully assess the selected ESP's

solutions and certifications to mitigate concerns about logistics data security and confidentiality. Adequate data protection measures are crucial to maintaining the integrity essential to guarantee the safety of the increasing use of ICT systems across various elements of logistics [34]. Logistics operations involve the entire process of producing and distributing a product or service, beginning with the acquisition and flow of raw materials and culminating in the final flow to the ultimate customer [35]. Therefore Measures for data protection and information security should be implemented throughout all supply chain activities. The transparency and traceability at each stage determine the achievable level of security [36].

In the competitive landscape of the cement and mining industries, FLSmidth has emerged as a global leader, providing innovative engineering solutions, equipment, and services to its clients worldwide. The company's expansive growth is evident through its presence in more than 50 offices globally, catering to the demands of the ever-evolving market. FLSmidth's success can be attributed to its dedication to providing sustainable productivity to its clientele is attained through an extensive range of industrial products and services in its portfolio. With expertise in key areas such as centrifugation, crushing, milling, and grinding, Tumbling mills are extensively used across various industries for grinding bulk materials [37]. FLSmidth has demonstrated performance excellence in the sectors it serves.

However, alongside its successes, FLSmidth, like many companies in the engineering and mining sectors, faces challenges inherent to these industries. Fluctuating commodity prices, economic uncertainties in different regions, and evolving environmental regulations pose ongoing challenges [38]. Additionally, managing a global supply chain in these sectors demands precision, safety, and efficiency. Sustaining uniformity and precision in material master data (MMD), incorporating descriptions and qualities of all acquired, manufactured, and stocked materials is crucial. Material Master Data refers to all the core information required to manage specific items within a supply chain, such as part numbers, descriptions, technical specifications, and stock codes. This data is central to logistics processes in a firm’s basic information management system Inadequate management of material master data can lead to inefficiencies, errors, and disruptions within the supply chain, impacting the company's overall operational performance. It can result in product returns and customer complaints, reduce the efficiency of supply chain operations, and endanger the level of stock [39,40].

The significance of addressing these challenges is underscored by the complexity of modern business operations. In this context, the implementation of Material Master Data Management (MMDM) practices becomes pivotal. MMDM involves standardizing and centralizing material master data elements, ensuring accuracy, consistency, and completeness. Effective MMDM practices streamline supply chain performance, optimize inventory management, and enhance operational efficiency.

Furthermore, integrating an external service provider like PiLog, an established player in the field, can significantly enhance the impact of MMDM implementation. PiLog, with its expertise in data cleaning, classification, master data governance, and material criticality analysis, aligns its services with international data quality standards such as ISO 8000. In today's data-driven world, organizations are increasingly acknowledging the crucial importance of Master Data Management (MDM) and Data Quality for improving business performance [41].

Considering the challenges faced by FLSmidth in its supply chain performance and the potential benefits offered by robust MMDM practices, studying how the management of MDM is implemented as the ability of the system to handle huge volumes of data as the business expands [42], and evaluating the moderating role of PiLog as an external service provider becomes imperative. Such a study can provide valuable insights into enhancing supply chain performance, ensuring data accuracy, completeness, and fostering sustainability in FLSmidth's logistics operations [43]. Additionally, understanding the dynamics of this implementation within the specific context of FLSmidth can contribute to broader knowledge in the field, offering practical implications for similar companies in the engineering and mining sectors.

2 Literature review

2.1 Master Data and Master Data Management

Master data, as outlined by [44], comprises vital entities within an organization, encompassing not just the entities themselves but also their definitions, classifications, and terminology that serve as the foundation of business information. Effectively gathering, managing, and utilizing data has become a crucial determinant of business success [45]. These essential reference data, such as the customers, chart of accounts, materials, and vendors play a critical role in preserving transactional integrity, aiding analysis, and ensuring compliance. Historically, master data management (MDM) evolved alongside advancements in technology, transitioning from flat data files to centralized computing systems [46]. Organizations began recognizing the significance of MDM, storing critical business data, including customer information, products, services, and supplier details [47].

Gartner Group's contributions, emphasizing MDM as both a technical and organizational challenge, underscored the multifaceted nature of MDM [48]. MDM, as a technology-driven discipline, aims to establish distinct identifiers for data entities like customers, suppliers, and products, facilitating unified data management [49]. The core of MDM lies in establishing an authoritative, precise, and singular source of organizational information assets [50,51]. This emphasis on data quality and governance is

crucial for ensuring supply chain performance**,** particularly in terms of operational efficiency and agility. The MDM model outlined by [52] includes content, systems, processes, governance, and establishing a strategic framework for proficient master data management.

The Resource-Based View (RBV) theory provides a robust theoretical foundation for understanding how master data and MDM can serve as valuable resources contributing to a firm's competitive advantage. According to RBV, resources that are valuable, rare, inimitable, and non-substitutable (VRIN) are crucial for sustaining a competitive edge. In the context of MDM, accurate and well-maintained master data can be seen as a strategic asset that enhances supply chain performance through metrics such as inventory turnover, order fulfillment accuracy, and lead time reduction. Previous research has applied RBV to explore how organizations leverage their data management capabilities to achieve superior performance. For instance, [54] examined the impact of master data management (MDM) on organizational performance through the Resource-Based View (RBV) theory. It posited that accurate master data is a critical resource characterized by value offering the strategic role of MDM in improving decision-making and operational efficiency.

Similarly, [55] investigated the impact of master data management (MDM) in enhancing supply chain performance, employing the Resource-Based View (RBV) theory. The study revealed how effective management of master data can influence supply chain efficiency and effectiveness. The study highlighted that well-managed master data serves as a critical resource, contributing to superior supply chain performance and providing a competitive edge.

However, there is a gap in the literature regarding the specific mechanisms through which MDM contributes to competitive advantage, particularly in the context of global supply chains. This study aims to address this gap by examining the role of MDM as a strategic resource in enhancing supply chain performance, drawing on the principles of RBV.

2.2 Material Master Data and MMDM in supply chain

Material master data management (MMDM) focuses specifically on materials an organization procures, produces, and stocks. Effective MMDM ensures standardized, accurate, and consistent material data, laying the foundation for streamlined supply chain operations. However, challenges in MMDM, especially within complex organizations like FLSmidth, require a nuanced approach. Implementing MMDM systems and addressing these challenges have far-reaching implications for supply chain performance.

The discussion on MMDM provides a comprehensive overview of its importance within modern business operations, especially within the domain of supply chain management. The authors aptly underline the critical role of well-maintained material master data in optimizing inventory, understanding material expenditure, and ultimately, ensuring efficient supply chain performance. The clear articulation of the historical evolution of Master Data Management (MDM) and its transition from flat data files to centralized computing systems adds depth to the discussion, establishing a solid foundation for understanding the complexities of MDM implementation.

2.3 The impact of MMDM on supply chain performance: the moderating role of PiLog external service provider

PiLog, an external service provider specializing in master data management, plays a crucial moderating role in the implementation of MMDM within organizations like FLSmidth. Their expertise and tools provide essential guidance, ensuring that MMDM practices align with industry standards and best practices. By moderating the implementation process, PiLog enhances the effectiveness of MMDM in optimizing supply chain performance. Investigating this moderating role in the context of FLSmidth is paramount, as it sheds light on how external service providers influence the outcome of MMDM initiatives, shaping the landscape of the supply chain performance within the organization.

Applying the RBV theory, PiLog's involvement can be interpreted as a strategic partnership that enhances the firm’s resource base. By providing specialized knowledge and technology, PiLog augments FLSmidth’s capabilities in managing material master data, thereby contributing to the firm’s competitive advantage. However, the literature has yet to thoroughly examine how such external collaborations influence the strategic value of MMDM. This study aims to address this gap by exploring the moderating role of PiLog in enhancing the strategic impact of MMDM within FLSmidth's supply chain, using RBV as a theoretical framework. The study also emphasizes how PiLog's involvement contributes to performance metrics such as lead time reduction, accurate order fulfillment, and inventory optimization, critical indicators of supply chain performance

However, while the importance of MMDM and the involvement of external service providers like PiLog are highlighted, the critique here lies in the lack of specific examples or case studies demonstrating the impact of MMDM, particularly within the context of FLSmidth. Providing concrete instances or real-life applications of MMDM implementation in organizations, especially in complex industrial settings like FLSmidth, would have strengthened the argument. Real-world examples would not only add credibility to the discussion but also offer practical insights into the challenges faced and the solutions implemented.

Furthermore, the moderating role of PiLog as an external service provider is briefly mentioned, but the nuances of their involvement are not elaborated upon. How exactly does PiLog navigate the unique challenges faced

by FLSmidth? What specific tools or strategies do they employ to moderate the implementation process effectively? These questions remain unanswered, leaving a gap in the understanding of PiLog's impact on MMDM within the organization.

3 Methodology

The research methodology adopted in this study, specifically focusing on the moderating role of PiLog External Service Provider (ESP), utilized a mono-qualitative approach. This choice was guided by the definition of qualitative research provided by [53], which describes it as a process of immersing oneself in the research to gain a deep understanding of the scenario. This approach is particularly well-suited for exploring the nuanced aspects of MMDM implementation, especially when considering the moderating influence. Additionally, the Resource-Based View (RBV) theory, which highlights the importance of an organization's internal resources and capabilities for achieving competitive advantage, further supports this exploration.

Despite potential criticisms of subjectivity in qualitative research [54], its appropriateness for this study lies in contextualizing MMDM within FLS through in-depth interviews, capturing participants' perspectives, and understanding the moderating role of PiLog.

The research questions were exploratory, centering on "What" and "How." Therefore, the exploratory approach was deemed necessary following suggestions by [55]. This study employed pragmatism; a philosophical approach selected to comprehend the implementation of MMDM in FLS under the moderating effects introduced by PiLog.

3.1 Research design

3.1.1 Units of analysis, population, and sampling

The study delved into MMDM implementation within FLS, PiLog, and PiLog's customer base, with a specific emphasis on PiLog's moderating role. We used purposive sampling to select participants whose data aligned with the study's objectives, focusing on the impact of PiLog on MMDM implementation. Non-probability purposive sampling ensured that FLS employees, PiLog Staff, and PiLog's customers met the study's criteria. A sample size of 25 respondents from FLS, 3 from PiLog, and 11 from PiLog's customer base was chosen considering the intricacies and complexities of MMDM.

3.1.2 Data collection

Data was collected through semi-structured interviews with 18 strategically selected employees from FLS and 4 of PiLog's main customers. The selection of employees was tactical, focusing on those involved in critical functions related to material master data management (MMDM), such as supply chain management, IT, and procurement, where they directly influence or manage the MMDM processes. Similarly, the customers selected were frequent or key customers who interact regularly with PiLog's services.

3.1.3 Data analysis

The data were analyzed using thematic analysis, which involved coding interview transcripts and identifying key themes related to MMDM and supply chain performance. The analysis, guided by the Resource-Based View (RBV) theory, focused on how FLS's internal resources, particularly MMDM, contribute to competitive advantage. Additionally, it explored how PiLog, as an external service provider, moderates these performance metrics, extending the RBV framework to include external factors in resource management. Patterns in interviewees' perceptions of PiLog's contributions were examined qualitatively to assess its moderating role in MMDM implementation.

3.1.4 Validity and reliability

Credibility was ensured through triangulation, aligning in-depth interviews with secondary data. Transferability was addressed as findings held general applicability to MMDM and supply chain performance, with a focus on the moderating role of PiLog. Dependability was established by rigorously conducting and aligning themes from literature with collected data. Objectivity (confirmability) was maintained through open and truthful reporting, preventing data misrepresentation [56].

The research methodology, guided by the research onion, aligned with the study's exploratory nature, emphasizing qualitative insights into MMDM implementation and its influence on supply chain performance in FLSmidth, with PiLog explicitly considered as a key moderating factor.

4 Results

4.1 Impact of Material Master Data Management (MMDM) implementation on supply chain performance in Flsmidth

The implementation of MMDM at FLSmidth, facilitated by PiLog, has demonstrated several positive impacts on supply chain performance, as supported by RBV theory**.** Enhanced visibility, better planning, reduced lead times, and increased stock availability contributed to improved inventory turnover, order fulfilment accuracy, and lead time reduction, key indicators of supply chain performance. These improvements align with RBV's assertion that strategic resources like MMDM can provide a competitive edge by optimizing internal processes and capabilities.

However, challenges emerged, particularly in convincing stakeholders of MMDM's value and accessing necessary databases and infrastructure. This deviation highlights a potential gap in the RBV application, where the expected seamless integration of internal resources (MMDM) was impeded by external factors like infrastructure and stakeholder resistance. This discrepancy

suggests that while RBV emphasizes the importance of internal resources, successful implementation also requires effective management of external constraints.

Standardization, as emphasized by PiLog, significantly contributed to improved supply chain performance. The implementation of Master Data Record Manager (MDRM), Structured Text Generation, and Technical Dictionary enhanced content quality and governance, which aligns with RBV's focus on leveraging resources for competitive advantage. Nonetheless, challenges in governance, such as integrating standardization practices within existing business structures, emerged as a notable issue. This finding underscores that while RBV provides a robust framework for understanding resource management, practical implementation may reveal additional complexities.

4.2 The moderating role of PiLog

PiLog's role as an External Service Provider (ESP) was instrumental in moderating MMDM implementation at FLSmidth. PiLog's structured frameworks and emphasis on standardization were crucial in overcoming challenges related to convincing stakeholders and accessing infrastructure. This supports RBV's perspective that external support can enhance the value derived from internal resources, aligning with the theory's assertion that strategic partnerships can optimize resource management.

PiLog's focus on governance and process management, particularly in data cleaning, played a significant moderating role. This involvement addressed some of the governance challenges faced by FLS, enhancing the effectiveness of MMDM implementation. The positive impact on visibility, planning, and inventory management reported by PiLog's customers further supports the RBV theory, demonstrating how effective external moderation can amplify the benefits of internal resources.

Unexpectedly, while PiLog's moderation improved MMDM outcomes, some issues persisted, such as stock visibility and planning inefficiencies at FLSmidth. These challenges indicate that external support alone may not fully address all internal resource management issues, highlighting a potential limitation in applying RBV solely focused on internal resources without considering the broader context.

5 Discussions

The study's findings demonstrate that Material Master Data Management (MMDM) at FLSmidth, supported by PiLog, aligns with the Resource-Based View (RBV) theory by enhancing visibility, planning, and inventory management, leading to improved supply chain performance. According to RBV, internal resources like MMDM can provide a competitive advantage if effectively managed [57]. At FLSmidth, the successful implementation of MMDM improved key performance metrics, reinforcing this theory. However, challenges related to stakeholder persuasion and infrastructure constraints reveal limitations of RBV, which assumes that internal resource management alone is sufficient for competitive advantage. This highlights the need to integrate RBV with additional frameworks to account for external influences on resource management.

The study further extends RBV by incorporating the moderating role of external service providers like PiLog. Traditionally, RBV focuses on leveraging internal resources for competitive advantage [58], but this study shows that external support can enhance the value of these resources. PiLog's structured frameworks and standardization practices addressed challenges such as stakeholder resistance, illustrating that strategic partnerships are essential for optimizing internal resource benefits. This finding offers a more nuanced understanding of RBV, emphasizing the role of external moderators in complex organizational settings.

Moreover, the study reveals that RBV alone cannot fully capture the complexities of MMDM implementation, as governance issues also play a crucial role.

Integrating Governance Theory with RBV provides a more comprehensive perspective on how internal resources and governance structures interact to influence supply chain performance. Practically, the study recommends strategic partnerships with external service providers to enhance MMDM, particularly in addressing stakeholder engagement and infrastructure challenges. It also suggests improving governance frameworks to optimize MMDM effectiveness and supply chain performance.

6 Conclusions

This study highlights the impact of Material Master Data Management (MMDM) on supply chain performance at FLSmidth, with PiLog, an External Service Provider (ESP), playing a moderating role. Utilizing the Resource-Based View (RBV) theory, the research frames MMDM as a strategic internal resource that enhances supply chain performance and competitive advantage. The study demonstrates that effective MMDM implementation improves visibility, planning, and inventory management, reinforcing FLS's competitive position. PiLog's external support further optimizes MMDM, illustrating the importance of strategic partnerships in maximizing internal resources.

However, the study also identifies limitations within the RBV framework, particularly in addressing external challenges like stakeholder persuasion, infrastructure access, and governance issues. These limitations suggest that RBV alone is insufficient for fully understanding the complexities of MMDM.For future research, integrating RBV with Governance and Institutional Theories is recommended to address both internal and external factors affecting MMDM. Governance Theory could explore how organizational structures influence resource management, while Institutional Theory could examine external pressures. Empirical studies on the long-term effects of ESPs like PiLog are also suggested to refine the theoretical

framework and improve MMDM practices across industries.

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