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Streamlining procurement processes in engineering and construction companies: A comparative analysis of best practices

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Abstract

The procurement process in engineering and construction (E&C) companies is a critical function that directly impacts project success, cost-efficiency, and schedule adherence. This study explores best practices in procurement, comparing their adoption and effectiveness across leading E&C organizations globally. By addressing challenges such as supplier evaluation, contract management, cost control, and supply chain risks, this analysis highlights strategies for streamlining procurement to achieve operational excellence. The research identifies digital transformation as a key driver, with technologies like Building Information Modeling (BIM), procurement automation, and data analytics enhancing visibility and decision-making across procurement cycles. Additionally, supplier relationship management (SRM) emerges as a vital practice, fostering collaboration and innovation while mitigating risks. Emphasis on sustainability is another critical trend, with green procurement and circular economy principles becoming standard practices in leading firms. A comparative analysis of case studies demonstrates the tangible benefits of integrating these practices. For example, automation and artificial intelligence in procurement have reduced processing times by over 30% in firms that adopted advanced solutions. Companies prioritizing SRM report enhanced supplier performance and resilience against disruptions. Furthermore, firms with robust sustainability frameworks have gained competitive advantages by aligning with global environmental and social governance (ESG) standards. This study concludes by offering actionable recommendations for procurement optimization, emphasizing the need for technology adoption, talent development, and robust risk management frameworks. By integrating these practices, E&C companies can improve efficiency, reduce costs, and enhance their competitive positioning in a dynamic market.

Keywords: Procurement Processes; Engineering and Construction; Best Practices; Digital Transformation; Building Information Modeling (BIM); Supplier Relationship Management (SRM); Green Procurement; Circular Economy; Sustainability; Operational Excellence

1. Introduction

This study aims to explore and analyze best practices in procurement within the E&C sector, drawing insights from leading organizations globally. By conducting a comparative analysis, the research seeks to identify innovative approaches and strategies that contribute to procurement excellence. The focus is on understanding how advanced technologies, supplier relationship management (SRM), and sustainable procurement initiatives are being adopted to enhance efficiency, cost-effectiveness, and overall project performance (Abuza, 2017, Ojebode & Onekutu, 2021).

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The relevance of this analysis lies in its potential to provide actionable insights for E&C companies seeking to optimize their procurement processes. By comparing diverse practices and their outcomes, this study offers a framework for adopting best practices that align with organizational goals and market demands. In doing so, it contributes to the broader discourse on improving operational efficiency and fostering innovation within the engineering and construction industry.

2. Literature Review

Procurement in engineering and construction (E&C) companies plays a fundamental role in ensuring that projects are completed on time, within budget, and to the required quality standards. The procurement process includes the acquisition of goods, services, and resources essential for the successful execution of construction projects. This process typically involves several key stages, including the identification of needs, the selection of suppliers, negotiation of contracts, and the management of procurement cycles (Calfa, et al., 2015, Olufemi-Phillips, et al., 2020). Given the complexity of construction projects, which often involve numerous stakeholders, materials, and timelines, efficient procurement is critical to project success. Effective procurement practices not only contribute to meeting project deadlines but also help in controlling costs, reducing risks, and maintaining quality standards.

In many E&C organizations, procurement practices are highly structured and are typically governed by policies that ensure transparency, fairness, and competitiveness. The procurement process often begins with the identification of a need for specific goods or services required for the project. This is followed by a detailed planning phase in which the specifications, costs, and timelines are carefully outlined. Tendering is the next stage, where potential suppliers are invited to submit proposals or bids for the required services or materials (Grandhi, Patwa & Saleem, 2021, Onukwulu, Agho & Eyo-Udo, 2022). Once a supplier is selected, contracts are negotiated and finalized, often including terms related to pricing, delivery schedules, and performance expectations. Procurement then transitions into the implementation phase, where purchase orders are issued, deliveries are monitored, and suppliers are managed.

Despite its importance, procurement in the E&C industry faces several challenges that complicate its efficiency and effectiveness. One of the most prominent issues is supplier selection and evaluation. E&C projects often require specialized materials and services, which means that selecting the right suppliers is crucial to achieving project goals. However, supplier selection is not always straightforward. E&C firms must evaluate a range of factors, including price, quality, reputation, delivery time, and capacity to meet project-specific requirements (Adewusi, Chiekezie & Eyo-Udo, 2022, Oyeniyi, et al., 2021). Additionally, firms must assess the financial stability and reliability of suppliers to ensure that they can fulfill long-term contracts without risk of failure. Inadequate or poor supplier evaluation can result in delays, cost overruns, or subpar materials and services that negatively impact project outcomes. Vehviläinen, 2019, presented framework for procurement process as shown in figure 1.

Figure 1 Framework (Vehviläinen, 2019)

Another challenge in procurement is contract management. Contract negotiation and administration in E&C projects are often complex, as they involve multiple parties, each with different interests and requirements. Contracts in this sector can be highly detailed and cover various aspects, such as payment schedules, scope of work, terms and conditions, and performance standards. The complexity of these contracts requires thorough oversight throughout the project

lifecycle. Poor contract management can lead to misunderstandings, disputes, and delays (Curuksu, 2018, Onukwulu, Agho & Eyo-Udo, 2021, Tseng, et al., 2021). Additionally, managing changes to contracts during the course of a project—due to design changes, scope adjustments, or unforeseen circumstances—can be difficult without a clear, transparent framework.

Cost overruns and supply chain disruptions are another set of significant challenges in procurement within the E&C industry. Construction projects are often subject to changes in scope, unforeseen conditions, or other factors that can impact costs. Managing procurement costs and ensuring that expenditures remain within budget is a continual challenge. Moreover, delays in the supply chain, whether caused by external factors such as geopolitical events, natural disasters, or internal inefficiencies, can result in project delays (Adewusi, Chiekezie & Eyo-Udo, 2022, Onukwulu, Agho & Eyo-Udo, 2022). In such cases, procurement professionals must manage risks associated with these disruptions by diversifying suppliers, maintaining strategic inventories, or renegotiating contracts. Ensuring that these challenges are minimized or mitigated is a critical part of streamlining procurement processes in the industry. Figure 2 shows generic Public Procurement Process as presented by Panda & Sahu, 2014.

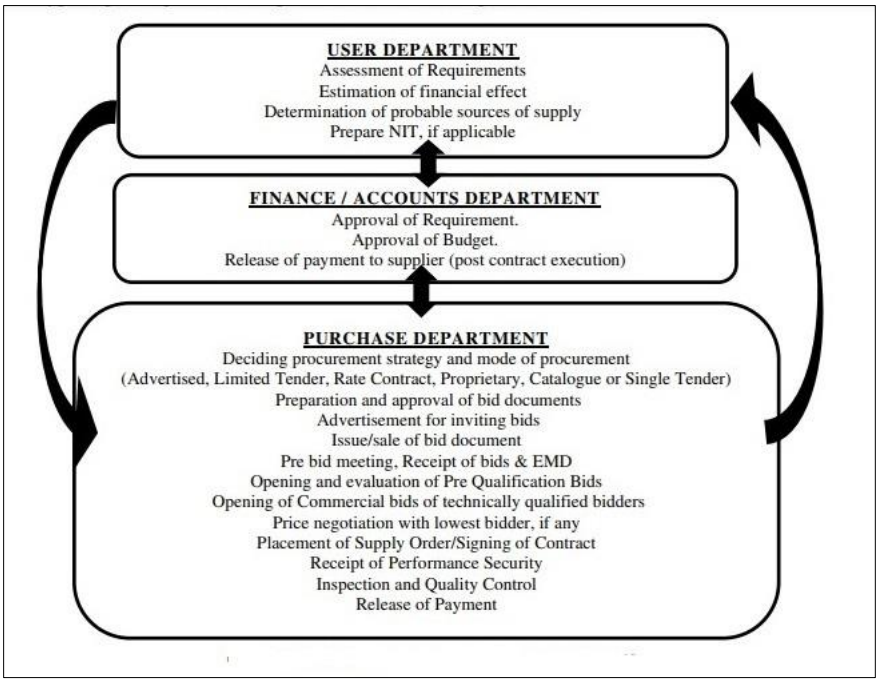

Figure 2 Generic Public Procurement Process (Panda & Sahu, 2014)

Emerging trends in procurement practices are shaping the future of the E&C industry. One of the most influential trends is digital transformation. The integration of digital tools and technologies has revolutionized the way procurement is managed, creating new efficiencies and opportunities for innovation (Gökalp, et al., 2021, Pora, et al., 2020). Building Information Modeling (BIM) is one such technology that is becoming increasingly widespread in the E&C sector. BIM allows for the digital representation of the physical and functional characteristics of a project, enabling procurement teams to visualize and coordinate procurement needs early in the project lifecycle (Alam, et al.,2019, Nguyen & Hadikusumo, 2018). This visualization helps to improve decision-making by providing more accurate information on costs, timelines, and potential risks. Procurement automation tools, including e-procurement platforms, are also increasingly being adopted, streamlining the process of issuing and managing purchase orders, managing supplier relationships, and tracking deliveries. These tools can also facilitate real-time updates on procurement status, allowing for quicker decision-making and more transparent procurement cycles.

Sustainability and green procurement have become significant drivers of change within the industry. As environmental regulations become stricter and clients demand more sustainable construction practices, E&C companies are focusing on incorporating sustainability into their procurement processes. Green procurement involves sourcing materials, services, and products that have minimal environmental impact throughout their lifecycle (Al Kaabi, 2021, Ordanini, Parasuraman & Rubera, 2014). This can include selecting suppliers that adhere to environmental best practices, sourcing sustainable materials, and ensuring that waste management and recycling protocols are followed. Companies that embrace green procurement practices are not only helping to meet regulatory requirements but are also enhancing

their corporate reputation and fulfilling the growing demand from clients for environmentally responsible construction practices. Furthermore, green procurement aligns with broader corporate social responsibility (CSR) goals and can contribute to long-term cost savings by focusing on resource efficiency and energy conservation (Jones, 2014, Kayabay, et al., 2022).

Another critical trend is the increasing reliance on data-driven decision-making in procurement. The availability of big data, coupled with advanced analytics, has opened up new possibilities for improving procurement practices. By analyzing data on supplier performance, pricing trends, and past project outcomes, procurement professionals can make more informed decisions that lead to better cost control, improved supplier relationships, and optimized supply chain management (Al-Hajji & Khan, 2016, Osei-Kyei & Chan, 2015). Predictive analytics can also help E&C companies foresee potential disruptions or delays and take proactive steps to mitigate risks. The use of data analytics has become a crucial aspect of streamlining procurement, enabling companies to optimize processes and outcomes.

In conclusion, while procurement practices in E&C companies have traditionally been complex and challenging, emerging trends such as digital transformation, sustainability, and data-driven decision-making are reshaping the industry. These trends offer new opportunities to address long-standing challenges in supplier selection, contract management, and cost control. By embracing best practices and adopting innovative solutions, E&C companies can streamline their procurement processes, improve project outcomes, and enhance their competitiveness in a rapidly evolving industry (Dal Maso, 2019, Peng, et al., 2015).

3. Methodology

The methodology adopted for this study on streamlining procurement processes in engineering and construction (E&C) companies involves a comparative case study analysis of leading organizations in the sector. The comparative approach was chosen to provide a comprehensive understanding of how different companies implement best practices in procurement, and to identify the factors that contribute to procurement efficiency, cost control, and improved project outcomes. By examining multiple case studies from different geographical regions and organizational contexts, the study seeks to draw generalizable insights about the best procurement practices within the E&C industry (Amirtash, Parchami Jalal & Jelodar, 2021, Pal, Wang & Liang, 2017).

The primary data collection for this study involved conducting in-depth interviews with procurement managers and industry experts. These interviews aimed to gather first-hand insights into the procurement processes, challenges, and innovations that are shaping the E&C sector. Procurement managers, who are responsible for overseeing the procurement functions within their organizations, were selected for their practical experience in managing procurement processes and supplier relationships (Arundel, Bloch & Ferguson, 2019, Panda & Sahu, 2014). Industry experts, including consultants, academics, and thought leaders, were chosen to provide a broader perspective on emerging trends, technologies, and strategic approaches in procurement. The interviews were semi-structured, allowing for flexibility in exploring topics while ensuring that key areas of interest were addressed. The goal was to collect qualitative data on the decision-making processes, technology adoption, supplier management strategies, and procurement challenges faced by E&C firms (Elouataoui, et al., 2022, Saiod, Van Greunen & Veldsman, 2017).

Secondary data was also an essential component of the research methodology. Industry reports, journal articles, and organizational records were reviewed to provide a broader understanding of procurement trends, challenges, and best practices in the E&C sector. These secondary sources helped contextualize the findings from the interviews and provided additional evidence on the current state of procurement in the industry (Boda & Immaneni, 2019, Ross & Ross, 2015). Industry reports, published by professional associations and market research firms, offered valuable insights into the latest procurement innovations, technological advancements, and strategic shifts in the E&C sector. Journal articles provided theoretical frameworks and empirical evidence on procurement practices, while organizational records, such as procurement policies and contract documents, helped to further understand the operational practices and formal structures within the case study companies. A chart showing procurement current situation by Vehviläinen, 2019, is shown in figure 3.

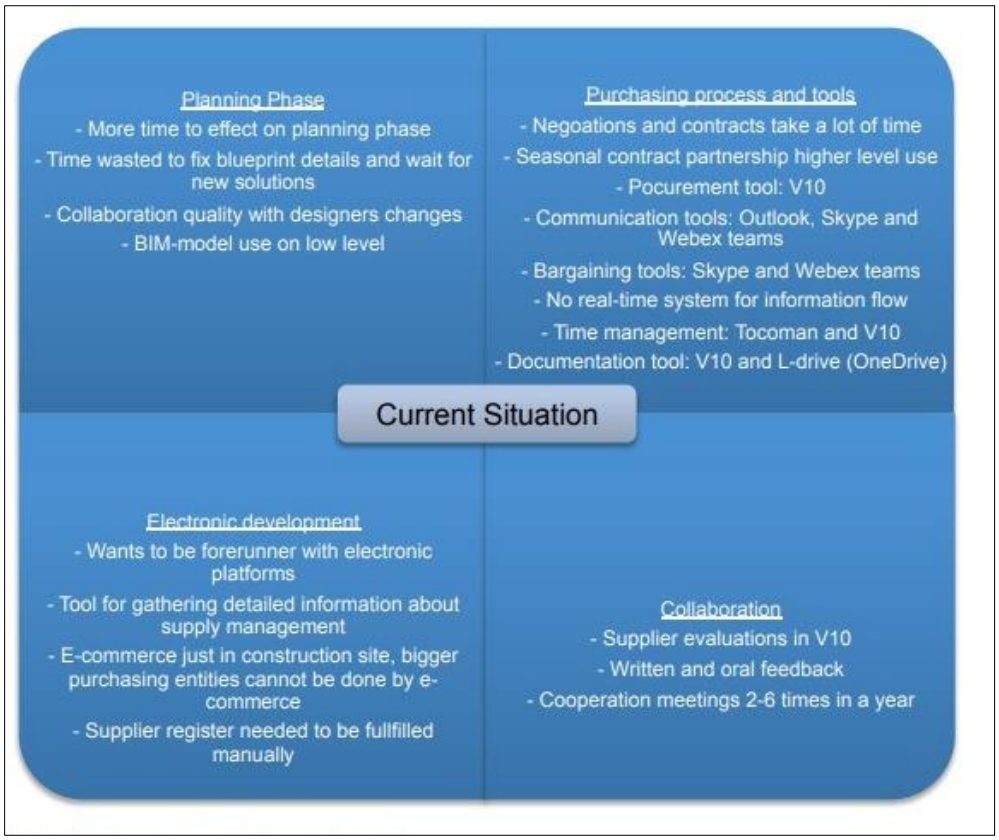

Figure 3 Procurement Current Situation (Vehviläinen, 2019)

Data analysis for this study employed both qualitative and quantitative techniques. Thematic analysis was used to analyze the qualitative data gathered from the interviews. This approach involved identifying recurring themes, patterns, and insights that emerged from the interview responses. Thematic analysis helped to organize and categorize the data, allowing for a deeper understanding of the common practices, challenges, and strategies that were shared across different organizations (Castro, 2019, Salamkar & Allam, 2019). Key themes identified in the interviews were then compared and contrasted to uncover best practices in procurement and to identify variations in procurement approaches based on company size, geographic location, and maturity level.

In addition to qualitative analysis, quantitative metrics were used to assess the effectiveness of procurement practices. Metrics such as cost savings, time efficiency, supplier performance, and procurement cycle time were compared across the case study companies. By analyzing these metrics, the study aimed to identify which procurement practices had the most significant impact on cost control, project timelines, and overall procurement efficiency. For instance, companies that adopted procurement automation or supplier relationship management (SRM) strategies were compared in terms of cost savings and reduced procurement cycle times. Similarly, firms that implemented green procurement initiatives were assessed based on their ability to achieve sustainability goals while maintaining cost-effectiveness (Chan, 2020, Sandilya & Varghese, 2016).

The selection of case studies was guided by specific criteria to ensure that the research captured a diverse range of procurement practices and organizational contexts. Geographic diversity was an essential factor, as procurement practices can vary significantly across regions due to local market conditions, regulatory frameworks, and cultural factors. By including case study companies from different geographical locations, the study aimed to highlight regional variations in procurement practices and identify global trends that could be applied across diverse markets (Hashem, et al., 2015, Siddiqa, et al., 2016).

Company size and procurement maturity level were also key criteria for selecting case studies. E&C firms range from small contractors to large multinational corporations, and procurement practices can differ based on the size and complexity of the organization. Smaller firms may have more informal procurement processes, while larger organizations may have more structured and standardized procedures (Deep, et al., 2022, Silwimba, 2019, Whitehead, 2017). By including a mix of company sizes, the study sought to identify procurement practices that are effective for

organizations of different scales and complexities. Furthermore, procurement maturity—referring to the extent to which an organization has developed and refined its procurement processes—was an important factor in selecting case studies (Laranjeiro, Soydemir & Bernardino, 2015). Companies with high procurement maturity were likely to have more sophisticated practices and the capacity to implement advanced procurement technologies such as e-procurement platforms, automation, and data analytics. Organisational barriers to e-Procurement implementation as presented by Panda & Sahu, 2014, is shown in figure 4.

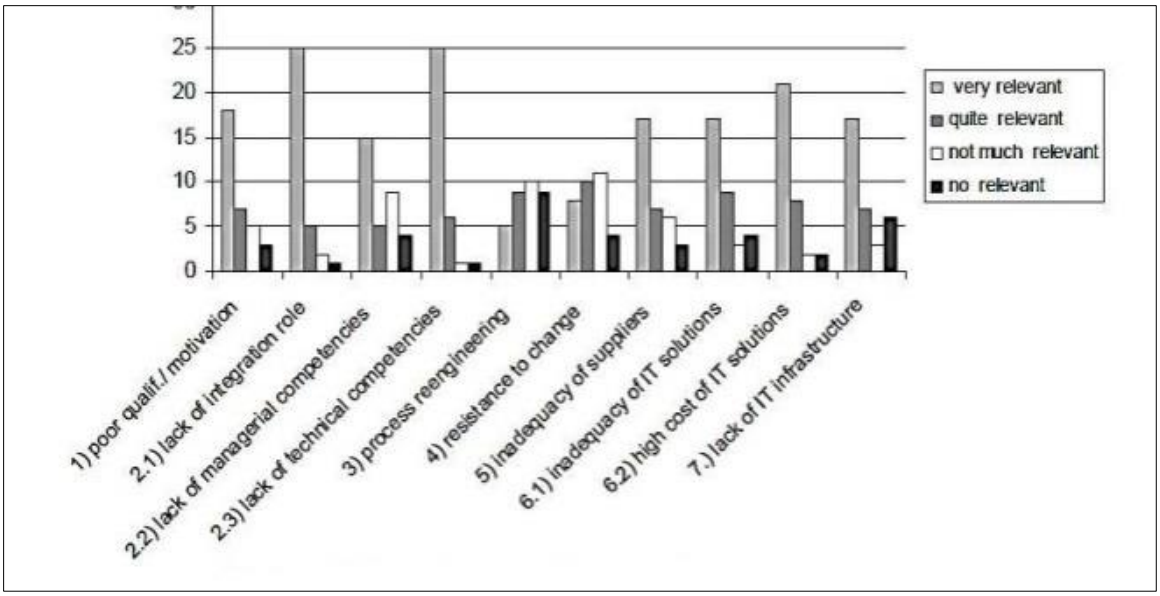

Figure 4 Organisational barriers to e-Procurement implementation (Panda & Sahu, 2014)

The adoption of innovative procurement practices was another critical criterion for selecting case studies. Companies that were early adopters of procurement technologies, such as Building Information Modeling (BIM), automation, or artificial intelligence (AI), were prioritized, as these innovations are transforming the procurement landscape in the E&C industry. The study aimed to explore how these advanced practices are being implemented, what challenges are faced, and what benefits are realized (Diaz, et al., 2021, Singh & Abhinav Parashar, 2021). Additionally, companies that had adopted sustainability-focused procurement practices, such as green procurement or circular economy initiatives, were also included in the case study selection. This allowed the study to assess the role of sustainability in shaping procurement processes and to evaluate the impact of green procurement on cost control, supplier relationships, and project outcomes.

The methodology also ensured that a diverse range of procurement practices was covered. This diversity was important in uncovering the factors that contribute to successful procurement strategies in the E&C sector. By examining case studies from companies with different approaches to procurement, the study was able to draw insights on which practices were most effective for streamlining procurement processes and achieving project success (Ebrahim, Battilana & Mair, 2014, Soni & T. Krishnan, 2014). The comparative nature of the analysis also allowed for the identification of trends and common practices that could be applied across different organizational contexts, helping to create a set of best practices that could be adopted by E&C companies globally.

In conclusion, the methodology for this study combines a comparative case study approach with both qualitative and quantitative data analysis to provide a comprehensive understanding of procurement best practices in the E&C industry. By gathering data from interviews with procurement managers and industry experts, along with secondary sources such as industry reports and organizational records, the study aims to identify key procurement strategies, challenges, and innovations (Filatotchev, Ireland & Stahl, 2022, Srivastava, et al., 2022). The case study selection criteria, including geographic diversity, company size, procurement maturity, and adoption of innovative practices, ensure that the research captures a wide range of procurement approaches and offers actionable insights for E&C firms seeking to streamline their procurement processes and improve project outcomes.

4. Key Findings

The key findings of this comparative analysis of procurement processes in engineering and construction (E&C) companies highlight several best practices, trends, and outcomes that have emerged across leading organizations in the sector. These findings offer insights into how procurement processes can be streamlined to enhance efficiency, reduce costs, and improve project outcomes. Based on an extensive analysis of case studies, industry reports, and interviews with procurement managers and experts, the following findings emerged as critical to improving procurement practices in E&C firms (Frota Barcellos, 2019, Steyn, 2014).

The adoption of procurement automation and artificial intelligence (AI) emerged as one of the most significant trends in streamlining procurement processes. Leading E&C firms are increasingly leveraging automation tools to manage procurement workflows, reduce manual effort, and minimize errors. Automated systems have enabled companies to improve the efficiency and accuracy of tasks such as order processing, invoice management, and supplier communications (Hossain, 2018, Syed, et al., 2020, Watson, et al., 2018). Automation not only speeds up the procurement cycle but also provides greater transparency, allowing procurement teams to track and monitor every step of the process in real-time. Artificial intelligence, in particular, is being used to enhance supplier selection, demand forecasting, and risk management. AI algorithms analyze vast amounts of data to predict procurement needs, optimize inventory levels, and identify potential risks in the supply chain. The integration of AI into procurement processes has led to cost savings, time reductions, and improved decision-making capabilities across the case study companies.

Another key best practice identified in the study is the integration of Building Information Modeling (BIM) in procurement. BIM has become an essential tool for E&C firms, especially for large-scale projects. By creating a digital representation of the physical and functional characteristics of a project, BIM facilitates better collaboration between stakeholders, including designers, engineers, suppliers, and contractors. BIM helps procurement teams by providing a clear and detailed overview of the materials, equipment, and resources required for a project, enabling more accurate forecasting and procurement planning (Ibrahim, 2015, Tezel, et al., 2020). It also enhances communication and coordination between different teams, reducing the risk of delays and cost overruns. The case studies revealed that companies that implemented BIM saw improvements in project delivery times, cost accuracy, and resource management, contributing to overall project success.

Effective supplier relationship management (SRM) strategies were also identified as a key driver of procurement efficiency. Leading E&C companies have recognized that strong, collaborative relationships with suppliers are essential for ensuring timely delivery, quality control, and cost management. SRM strategies focus on building long-term partnerships with key suppliers based on mutual trust, transparency, and performance-based metrics. The case studies highlighted that firms that invested in SRM were able to secure better pricing, optimize lead times, and reduce the risk of supply chain disruptions (Kabirifar & Mojtahedi, 2019, Thamrin, 2017). Furthermore, SRM practices enable companies to proactively address issues such as quality control, compliance, and contract management. In some cases, E&C firms adopted supplier performance scorecards to monitor and evaluate supplier performance on key metrics, such as on-time delivery, quality, and cost adherence. These performance evaluations allowed companies to make data-driven decisions about supplier selection and identify areas for improvement in their supplier base (Navarro, 2017).

Sustainability and green procurement initiatives were also found to be an integral part of the procurement process in leading E&C firms. As the construction industry faces increasing pressure to reduce its environmental footprint, many companies are incorporating sustainability into their procurement practices. Green procurement involves selecting suppliers and materials based on their environmental impact, including factors such as energy consumption, waste generation, and carbon emissions (Liu, Wang & Wilkinson, 2016, Thumburu, 2020). The study found that companies that embraced sustainable procurement practices were able to meet regulatory requirements, enhance their corporate social responsibility (CSR) reputation, and achieve cost savings through energy-efficient and environmentally friendly materials. Green procurement also fostered innovation in the supply chain, with suppliers developing new products and technologies that met sustainability criteria. For instance, some E&C firms integrated circular economy principles into their procurement strategy, opting for reusable or recyclable materials to reduce waste and lower costs (Sturtevant, et al., 2022, Vallejo-Vaz, et al., 2016). These practices contributed to the overall sustainability goals of the firms and provided a competitive advantage in a market increasingly focused on environmental performance.

The comparative analysis of case studies provided valuable insights into the successes and challenges experienced by E&C companies as they implemented these procurement best practices. The success stories highlighted measurable outcomes, such as reductions in procurement cycle time, cost savings, and improved project delivery. For example, one multinational construction firm that adopted procurement automation and AI reported a 25% reduction in procurement processing time, leading to faster project completion and a 15% reduction in procurement costs (Micheli

& Cagno, 2016, Toutounchian, et al., 2018). Another case study showed how the integration of BIM allowed a construction company to complete a major infrastructure project 10% under budget and 20% ahead of schedule. These measurable outcomes demonstrate the significant impact that procurement innovations can have on project performance.

However, the case studies also revealed areas for improvement in some companies' procurement processes. One of the key challenges faced by E&C firms was the integration of new procurement technologies into existing systems. Despite the advantages offered by automation and AI, some companies struggled with the initial implementation phase, facing issues such as resistance to change, inadequate training, and difficulties in integrating new tools with legacy systems (Mohanty, Choppali & Kougianos, 2016, Van Zyl, Mathafena & Ras, 2017). In some cases, firms experienced delays in realizing the full benefits of these technologies due to these implementation challenges. Another area for improvement was in the area of supplier relationship management. While many firms recognized the importance of strong supplier relationships, some companies still faced difficulties in maintaining effective communication and collaboration with suppliers, particularly when working with multiple vendors across different regions. In some cases, the lack of standardized procurement processes and performance metrics hindered the ability to effectively evaluate supplier performance and make data-driven decisions about supplier selection.

In addition, while sustainability and green procurement initiatives were widely adopted by many E&C companies, the study found that some firms faced challenges in quantifying the environmental impact of their procurement decisions. Measuring the true environmental impact of materials and suppliers can be complex, requiring detailed life cycle assessments and data from multiple sources. Some companies struggled to balance sustainability goals with cost constraints, as eco-friendly materials and technologies can sometimes be more expensive than traditional alternatives (Moretto, et al., 2022, Vehviläinen, 2019, Vilasini, Neitzert & Rotimi, 2011). This highlights the need for further innovation in the green procurement space, including the development of standardized metrics and tools that can help firms better evaluate the environmental performance of their procurement choices.

The case studies also underscored the importance of continuous improvement and ongoing evaluation of procurement practices. Many of the leading E&C firms that participated in the study emphasized the need for regular reviews of procurement processes to identify bottlenecks, optimize workflows, and adapt to changing market conditions. Procurement teams that were proactive in seeking feedback from suppliers, stakeholders, and project teams were able to refine their practices over time, leading to improved outcomes in subsequent projects (Ali & Hussain, 2017, Bhaskaran, 2019).

In conclusion, the key findings of this study underscore the importance of adopting best practices in procurement to streamline processes and achieve better project outcomes in the E&C sector. The integration of procurement automation, artificial intelligence, Building Information Modeling (BIM), supplier relationship management, and sustainability initiatives emerged as key drivers of procurement efficiency and project success. The case studies provided valuable insights into the measurable benefits of these practices, as well as the challenges that companies face when implementing them. Overall, these findings highlight the significant role that procurement can play in enhancing project delivery, reducing costs, and improving sustainability in the construction industry.

5. Discussion

The discussion surrounding the streamlining of procurement processes in engineering and construction (E&C) companies reveals several critical factors contributing to the successful implementation of best practices, as well as challenges that may hinder progress. This analysis, grounded in case studies and industry reports, underscores the complexity and significance of procurement processes within the E&C sector. By identifying both the drivers of success and the barriers to improvement, the findings provide valuable insights into how procurement can evolve and support broader business objectives in the industry (Ansell & Gash, 2018, Turban, Pollard & Wood, 2018).

A significant factor contributing to successful procurement practices in E&C companies is the adoption of technology. As highlighted in previous sections, companies are increasingly leveraging automation, artificial intelligence (AI), and other digital tools to enhance the efficiency and effectiveness of their procurement operations. Technology has proven to be an enabler in streamlining procurement workflows, reducing errors, and improving data accuracy (Asch, et al., 2018, Benlian, et al.. 2018). Automated procurement systems allow for faster processing of orders, invoicing, and payments, while AI algorithms can assist in demand forecasting, supplier selection, and risk management. These technologies reduce the need for manual interventions, cutting down processing times and improving accuracy, ultimately contributing to cost savings and improved procurement outcomes. Furthermore, Building Information Modeling (BIM) has become an indispensable tool in the procurement process for large-scale construction projects. By

creating digital representations of project details, BIM enables real-time collaboration among different teams, helping procurement professionals to forecast material and resource needs more accurately. BIM's ability to provide detailed, up-to-date information about a project's requirements helps procurement teams make more informed decisions, ultimately reducing delays, costs, and procurement errors.

Equally important in achieving successful procurement practices is the establishment of effective collaboration and communication frameworks. The nature of E&C projects often requires coordination among multiple stakeholders, including procurement teams, project managers, engineers, contractors, and suppliers (Barns, 2018, Zutshi, Grilo & Nodehi, 2021). In this environment, clear communication and collaboration are vital for successful procurement. Strong relationships with suppliers, built on mutual trust, transparency, and clear expectations, have been identified as a crucial factor in optimizing procurement processes. Procurement teams that engage with suppliers early in the project lifecycle, establish clear communication channels, and ensure mutual understanding of project goals are more likely to benefit from timely deliveries, competitive pricing, and high-quality materials. Additionally, the integration of digital communication tools, such as cloud-based platforms and real-time messaging systems, helps facilitate the exchange of information between project teams and suppliers, reducing the risk of misunderstandings or delays.

Risk management and mitigation strategies also play a central role in the successful execution of procurement practices in E&C companies. Procurement teams must address a wide range of risks, including supply chain disruptions, price fluctuations, quality issues, and regulatory compliance concerns. Leading E&C firms have developed proactive risk management strategies that help identify, assess, and mitigate potential risks before they become significant challenges. These strategies often involve the use of advanced data analytics to predict and manage potential procurement risks (Volberda, et al., 2021, Yi, et al., 2017). For example, AI-based predictive tools can analyze historical data to identify potential supply chain disruptions, allowing procurement teams to make informed decisions about inventory levels, supplier contracts, and procurement timelines. In addition, establishing long-term partnerships with reliable suppliers and diversifying the supplier base helps mitigate the risk of relying on a single source for critical materials, especially in global supply chains where geopolitical or economic instability can impact supply availability. Effective risk management strategies help ensure that procurement processes remain smooth, even in the face of external challenges, thereby improving project outcomes and reducing costs.

Despite the success of these best practices, the implementation of streamlined procurement processes in E&C companies is not without its challenges. One of the most common obstacles is the resistance to change, especially when introducing new technologies or practices. E&C companies, like many others, often operate with entrenched processes and workflows that have been in place for many years (Yu, et al., 2017, Zachariadis, Hileman & Scott, 2019). Procurement teams may be reluctant to adopt new systems or technologies due to concerns about cost, disruption to ongoing projects, or a lack of expertise. This resistance can slow down the pace of digital transformation and hinder the full realization of the benefits associated with procurement optimization. Furthermore, companies may encounter difficulties in integrating new technologies with existing legacy systems, resulting in data inconsistencies, inefficiencies, and delays. Effective change management strategies, including training programs, stakeholder engagement, and gradual implementation of new tools, can help mitigate these challenges and ease the transition to more efficient procurement practices.

Another challenge in implementing best practices is the complexity of the procurement environment itself. E&C projects are often large and complex, involving multiple contractors, suppliers, and subcontractors. Coordinating the procurement of materials, equipment, and services across a diverse group of stakeholders can be a daunting task, and any miscommunication or lack of coordination can lead to delays, cost overruns, or quality issues (Al-Ali, et al., 2016, Jones, et al., 2020). In addition, procurement managers in the E&C sector must navigate a wide range of regulatory requirements, including environmental regulations, labor laws, and health and safety standards, which can complicate decision-making and increase procurement costs. The diverse and often fragmented nature of the procurement landscape means that standardization of procurement processes can be challenging. Companies that operate in multiple regions or jurisdictions must also contend with varying local regulations and market conditions, making it difficult to implement consistent procurement practices across all projects.

Furthermore, some E&C companies face challenges related to supplier performance. Despite the emphasis on supplier relationship management (SRM), not all suppliers meet the performance expectations set by procurement teams. Issues such as late deliveries, quality inconsistencies, and non-compliance with contractual terms can disrupt the procurement process and hinder project timelines (Bitter, 2017, Rico, et al., 2018, Zou, et al., 2020). While SRM strategies can help mitigate these issues by fostering closer collaboration and performance monitoring, procurement teams may still face difficulties in managing underperforming suppliers, particularly in a global supply chain context where logistical complexities and differing standards may exacerbate issues. In such cases, procurement teams need to be proactive in

addressing supplier performance issues by engaging in constructive dialogue, setting clear expectations, and taking corrective action when necessary.

The implications of these findings for the E&C industry are significant. As the industry continues to face increasing pressures to deliver projects on time, within budget, and with high-quality standards, the streamlining of procurement processes has the potential to deliver substantial benefits. First, optimized procurement practices can lead to significant cost savings, as companies reduce procurement cycle times, minimize errors, and capitalize on economies of scale through better supplier negotiations. Second, procurement streamlining can improve project delivery by reducing delays and ensuring that materials and resources are available when needed (Chen, et al., 2020, Saarikallio, 2022). This improvement in efficiency can enhance an E&C firm's competitive edge by allowing it to complete projects more quickly and with greater cost control, positioning it favorably in a competitive market.

Third, the focus on sustainability in procurement practices has broader implications for the industry's environmental performance. As the construction sector is a major contributor to carbon emissions and resource consumption, incorporating sustainability into procurement strategies can help E&C firms meet regulatory requirements, improve their CSR profiles, and contribute to the industry's overall shift toward more environmentally responsible practices. The increased emphasis on green procurement also presents opportunities for innovation, as suppliers develop new products and technologies that meet environmental standards (Davis, 2014, Tang, Yilmaz & Cooke, 2018).

In conclusion, the successful streamlining of procurement processes in E&C companies hinges on the adoption of technology, the establishment of strong collaboration frameworks, and the implementation of effective risk management strategies. While challenges such as resistance to change, supply chain complexity, and supplier performance issues remain, the industry's focus on procurement optimization presents significant opportunities for improving project outcomes, reducing costs, and advancing sustainability. As the E&C sector continues to evolve, it will need to embrace these best practices to remain competitive and meet the growing demands for efficiency, quality, and environmental responsibility.

Recommendations

Streamlining procurement processes in engineering and construction (E&C) companies is essential for improving efficiency, reducing costs, and enhancing the overall success of projects. As companies within the sector continue to face increasing pressures to deliver projects on time and within budget, the need for optimized procurement practices has become more urgent. The comparative analysis of best practices in procurement reveals several key recommendations that can help E&C firms streamline their procurement processes, improve supplier relationships, and drive better project outcomes (Duo, et al., 2022, Zong, 2022). These recommendations cover strategies for streamlining procurement, investing in technology and talent development, and building more sustainable and resilient supply chains.

One of the most effective strategies for streamlining procurement processes in E&C companies is the adoption of procurement automation. Automating manual tasks such as order processing, invoice approval, and inventory management can significantly reduce the time and effort required to complete these activities. This, in turn, allows procurement teams to focus on more strategic activities, such as supplier relationship management and procurement planning. Automation can also help reduce errors and inconsistencies, improving data accuracy and minimizing costly mistakes. For example, automated procurement systems can ensure that materials and resources are ordered in the correct quantities and at the right time, reducing the risk of over-ordering or under-ordering (Vlietland, Van Solingen & Van Vliet, 2016, Zhang, et al., 2017). Additionally, procurement automation can help improve compliance by ensuring that all purchases are made in accordance with company policies and regulatory requirements. By automating these processes, E&C firms can not only increase efficiency but also enhance transparency and accountability in procurement activities.

In addition to automation, another key strategy for streamlining procurement processes is the adoption of digital tools such as Building Information Modeling (BIM). BIM allows for the creation of digital representations of physical and functional characteristics of a project, providing a collaborative platform for project teams to manage procurement more effectively. By using BIM, E&C firms can optimize the planning and sourcing of materials, minimize waste, and reduce the risk of procurement errors (Alessa, et al., 2016, Pace, Carpenter & Cole, 2015). The integration of BIM with procurement systems allows for real-time updates on material availability, costs, and delivery timelines, enabling procurement managers to make more informed decisions. Moreover, BIM enables a more seamless collaboration between procurement teams, contractors, suppliers, and other stakeholders, improving communication and reducing

the likelihood of misunderstandings or delays. This holistic approach to procurement, which incorporates both technology and collaboration, can lead to significant improvements in project delivery and cost management.

Another important recommendation for streamlining procurement in E&C companies is to invest in talent development. Procurement is a complex function that requires specialized knowledge and skills, particularly in the context of large-scale engineering and construction projects. Therefore, it is critical for companies to invest in the development of their procurement teams to ensure they have the expertise needed to manage procurement processes effectively. This investment in talent development can take several forms, including training programs, mentoring, and continuous learning opportunities (Asch, et al., 2018, Patel, et al., 2017). For example, E&C companies can provide their procurement teams with training in the latest procurement technologies, such as AI-driven procurement tools and data analytics, as well as best practices in supplier management, contract negotiation, and risk management. By equipping procurement professionals with the skills they need to succeed in an increasingly complex and fast-changing procurement landscape, companies can improve the performance of their procurement teams and enhance the overall efficiency of the procurement process.

Furthermore, developing talent in procurement involves not only technical skills but also soft skills, such as communication, negotiation, and relationship management. Procurement professionals who are adept at building strong relationships with suppliers and other stakeholders are better equipped to manage the challenges that arise during the procurement process. They can navigate complex negotiations, resolve conflicts, and ensure that procurement activities align with project goals and timelines. Therefore, E&C companies should emphasize the importance of developing well-rounded procurement professionals who possess both technical expertise and interpersonal skills (Bae & Park, 2014, Raza, 2021).

In addition to improving procurement capabilities, E&C companies should prioritize the creation of sustainable and resilient supply chains. The global nature of the construction industry means that companies often rely on a diverse range of suppliers from different geographic locations, which can expose them to risks such as supply chain disruptions, geopolitical tensions, and natural disasters. To mitigate these risks, E&C firms should focus on building supply chains that are not only efficient but also resilient and sustainable. This involves adopting practices such as diversifying the supplier base, building strong relationships with key suppliers, and ensuring that suppliers adhere to sustainability standards (Bhaskaran, 2020, Yu, et al., 2019). By diversifying the supplier base, E&C companies can reduce the risk of relying on a single supplier or region for critical materials, which can help mitigate the impact of disruptions caused by unforeseen events. Additionally, fostering strong relationships with suppliers can lead to more reliable deliveries, better pricing, and improved quality, all of which contribute to more efficient procurement processes.

Sustainability is also an increasingly important consideration for procurement in the E&C sector. As the industry faces growing pressure to reduce its environmental footprint, companies should incorporate sustainability criteria into their procurement decisions. This may involve sourcing materials from suppliers that prioritize environmental stewardship, using renewable or recycled materials, and minimizing waste throughout the procurement process. Implementing green procurement practices can not only help E&C firms meet regulatory requirements and corporate social responsibility (CSR) goals but also contribute to cost savings in the long run (Chinamanagonda, 2022, Pulwarty & Sivakumar, 2014). For example, by sourcing energy-efficient materials and technologies, companies can reduce energy consumption and lower operating costs over the life cycle of the project. Moreover, adopting sustainable procurement practices can enhance a company's reputation, making it more attractive to clients, investors, and other stakeholders who prioritize environmental responsibility.

Another key element in building resilient supply chains is the use of data-driven decision-making. E&C companies can leverage data analytics to gain deeper insights into their supply chains, identify potential risks, and improve procurement forecasting. Predictive analytics, for example, can help procurement teams anticipate demand fluctuations, identify potential supplier issues, and optimize inventory levels. By using data to make more informed decisions, companies can reduce the likelihood of supply chain disruptions and improve procurement outcomes (Ahmad, et al., 2022, Maja & Letaba, 2022). Additionally, the use of data analytics can enhance supplier performance management by providing procurement teams with actionable insights into supplier performance metrics, such as on-time delivery rates, quality standards, and compliance with contractual terms. This data-driven approach helps ensure that procurement decisions are based on objective information rather than assumptions or historical patterns.

Lastly, E&C firms should develop a strategic approach to supplier relationship management (SRM). Effective SRM is essential for streamlining procurement processes and improving supplier performance. Companies should focus on building long-term, collaborative relationships with their key suppliers rather than simply seeking the lowest-cost option. This involves engaging suppliers early in the project lifecycle, setting clear expectations, and working together

to solve problems as they arise (Becker, et al., 2016, Pora, et al., 2018). By fostering a collaborative approach to procurement, E&C firms can reduce procurement risks, improve material quality, and ensure timely deliveries. Furthermore, strong supplier relationships can create opportunities for innovation, as suppliers may bring new ideas or technologies to the table that can improve project outcomes.

In conclusion, streamlining procurement processes in E&C companies requires a multifaceted approach that includes adopting automation and digital tools, investing in talent development, and building sustainable and resilient supply chains. By implementing these recommendations, companies can improve procurement efficiency, reduce costs, and enhance project delivery. Moreover, a focus on sustainability and resilience can help E&C firms navigate the challenges of an increasingly complex and volatile global marketplace (Curuksu, 2018, Zolnowski, Christiansen & Gudat, 2016). As the E&C sector continues to evolve, these best practices will be essential for maintaining competitiveness and achieving long-term success.

6. Conclusion

In conclusion, streamlining procurement processes within engineering and construction (E&C) companies is essential for improving efficiency, reducing costs, and ensuring successful project outcomes. The comparative analysis of best practices has highlighted several key strategies that can significantly enhance procurement functions. The adoption of automation and digital tools, such as procurement automation and Building Information Modeling (BIM), has proven to be a game-changer, allowing companies to optimize procurement planning, reduce errors, and improve collaboration. Additionally, the integration of advanced technologies, like artificial intelligence and data-driven decision-making, can further streamline processes by providing real-time insights and enhancing forecasting accuracy.

Equally important is the investment in talent development, which enables procurement teams to adapt to evolving demands and complexities within the industry. Building a skilled workforce with expertise in both technical and soft skills is crucial to overcoming procurement challenges and driving continuous improvement. Supplier relationship management and the establishment of strong, long-term partnerships with key suppliers emerged as critical elements for ensuring procurement success. Companies that prioritize collaboration and communication with their suppliers tend to experience fewer disruptions, enhanced product quality, and better overall project performance.

The comparative analysis of case studies revealed numerous success stories, demonstrating the positive impact of streamlined procurement processes on project timelines, cost management, and overall outcomes. These best practices serve as valuable benchmarks for other E&C firms aiming to improve their procurement practices. However, the study also identified areas for improvement, particularly in terms of overcoming challenges related to supply chain disruptions, cost overruns, and contract management complexities. These insights provide a foundation for continuous enhancement of procurement processes across the industry.

This research contributes valuable knowledge to the field of procurement in E&C companies, offering practical recommendations for streamlining procurement processes and fostering more sustainable, resilient supply chains. It underscores the importance of technology adoption, collaboration, and talent development as key drivers of procurement excellence. Additionally, the findings highlight the need for companies to embrace sustainability in their procurement decisions, aligning with broader industry trends and regulatory pressures.

Looking forward, there are several opportunities for future research in this area. Further studies could explore the long-term impact of procurement best practices on project success and profitability, as well as the role of emerging technologies in shaping the future of procurement in E&C companies. Additionally, research focused on the integration of sustainability and green procurement practices in the supply chain could provide deeper insights into how E&C companies can balance operational efficiency with environmental responsibility. Overall, continued exploration of procurement strategies and innovations will be essential for E&C firms aiming to remain competitive in an ever-evolving industry landscape.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abuza, A. E. (2017). An examination of the power of removal of secretaries of private companies in Nigeria. Journal of Comparative Law in Africa, 4(2), 34-76.

[2] Adewusi, A.O., Chiekezie, N.R. & Eyo-Udo, N.L. (2022) Cybersecurity threats in agriculture supply chains: A comprehensive review. World Journal of Advanced Research and Reviews, 15(03), pp 490-500

[3] Adewusi, A.O., Chiekezie, N.R. & Eyo-Udo, N.L. (2022) Securing smart agriculture: Cybersecurity challenges and solutions in IoT-driven farms. World Journal of Advanced Research and Reviews, 15(03), pp 480-489

[4] Adewusi, A.O., Chiekezie, N.R. & Eyo-Udo, N.L. (2022) The role of AI in enhancing cybersecurity for smart farms. World Journal of Advanced Research and Reviews, 15(03), pp 501-512

[5] Ahmad, T., Aakula, A., Ottori, M., & Saini, V. (2022). Developing A Strategic Roadmap For Digital Transformation. Journal of Computational Intelligence and Robotics, 2(2), 28-68.

[6] Akter, S., Hossain, M. A., Lu, Q., & Shams, S. R. (2021). Big data-driven strategic orientation in international marketing. International Marketing Review, 38(5), 927-947.

[7] Al Kaabi, M. S. H. (2021). Factors Influencing Timely Completion Of Construction Projects In The Oil Industry In The United Arab Emirates-An Exploratory Study (Doctoral dissertation, Aberystwyth University, UK).

[8] Al-Ali, R., Kathiresan, N., El Anbari, M., Schendel, E. R., & Zaid, T. A. (2016). Workflow optimization of performance and quality of service for bioinformatics application in high performance computing. Journal of Computational Science, 15, 3-10.

[9] Alam, M., Zou, P. X., Stewart, R. A., Bertone, E., Sahin, O., Buntine, C., & Marshall, C. (2019). Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. Sustainable Cities and Society, 44, 56-69.

[10] Alessa, L., Kliskey, A., Gamble, J., Fidel, M., Beaujean, G., & Gosz, J. (2016). The role of Indigenous science and local knowledge in integrated observing systems: moving toward adaptive capacity indices and early warning systems. Sustainability Science, 11, 91-102.

[11] Al-Hajji, H., & Khan, S. (2016, November). Keeping oil & gas EPC major projects under control: strategic & innovative project management practices. In Abu Dhabi International Petroleum Exhibition and Conference (p. D021S033R003). SPE.

[12] Amirtash, P., Parchami Jalal, M., & Jelodar, M. B. (2021). Integration of project management services for International Engineering, Procurement and Construction projects. Built Environment Project and Asset Management, 11(2), 330-349.

[13] Arundel, A., Bloch, C., & Ferguson, B. (2019). Advancing innovation in the public sector: Aligning innovation measurement with policy goals. Research policy, 48(3), 789-798.

[14] Asch, M., Moore, T., Badia, R., Beck, M., Beckman, P., Bidot, T., ... & Zacharov, I. (2018). Big data and extreme-scale computing: Pathways to convergence-toward a shaping strategy for a future software and data ecosystem for scientific inquiry. The International Journal of High Performance Computing Applications, 32(4), 435-479.

[15] Bae, M. J., & Park, Y. S. (2014). Biological early warning system based on the responses of aquatic organisms to disturbances: a review. Science of the Total Environment, 466, 635-649.

[16] Becker, T., Curry, E., Jentzsch, A., & Palmetshofer, W. (2016). New Horizons for a Data-Driven Economy: Roadmaps and Action Plans for Technology, Businesses, Policy, and Society.

[17] Bhaskaran, S. V. (2020). Integrating Data Quality Services (DQS) in Big Data Ecosystems: Challenges, Best Practices, and Opportunities for Decision-Making. Journal of Applied Big Data Analytics, Decision-Making, and Predictive Modelling Systems, 4(11), 1-12.

[18] Bitter, J. (2017). Improving multidisciplinary teamwork in preoperative scheduling (Doctoral dissertation, [Sl]:[Sn]).

[19] Boda, V. V. R., & Immaneni, J. (2019). Streamlining FinTech Operations: The Power of SysOps and Smart Automation. Innovative Computer Sciences Journal, 5(1).

[20] Calfa, B. A., Agarwal, A., Bury, S. J., Wassick, J. M., & Grossmann, I. E. (2015). Data-driven simulation and optimization approaches to incorporate production variability in sales and operations planning. Industrial & engineering chemistry research, 54(29), 7261-7272.

[21] Castro, R. (2019). Blended learning in higher education: Trends and capabilities. Education and Information Technologies, 24(4), 2523-2546.

[22] Chan, N. (2020). Building Information Modelling: An analysis of the methods used to streamline design-to-construction in New Zealand (Doctoral dissertation, Open Access Te Herenga Waka-Victoria University of Wellington).

[23] Chen, Q., Hall, D. M., Adey, B. T., & Haas, C. T. (2020). Identifying enablers for coordination across construction supply chain processes: a systematic literature review. Engineering, construction and architectural management, 28(4), 1083-1113.

[24] Chinamanagonda, S. (2022). Observability in Microservices Architectures-Advanced observability tools for microservices environments. MZ Computing Journal, 3(1).

[25] Curuksu, J. D. (2018). Data driven. Management for Professionals.

[26] Curuksu, J. D. (2018). Data driven. Management for Professionals.

[27] Dal Maso, A. (2019). The evolution of Data Governance: a tool for an improved and enhanced decision-making process.

[28] Davis, J. E. (2014). Temporal meta-model framework for Enterprise Information Systems (EIS) development (Doctoral dissertation, Curtin University).

[29] Deep, S., Banerjee, S., Dixit, S., & Vatin, N. I. (2022). Critical factors influencing the performance of highway projects: an empirical evaluation. Buildings, 12(6), 849.

[30] Diaz, A., Schöggl, J. P., Reyes, T., & Baumgartner, R. J. (2021). Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management. Sustainable Production and Consumption, 26, 1031-1045.

[31] Duo, X., Xu, P., Zhang, Z., Chai, S., Xia, R., & Zong, Z. (2022, October). KCL: A Declarative Language for Large-Scale Configuration and Policy Management. In International Symposium on Dependable Software Engineering: Theories, Tools, and Applications (pp. 88-105). Cham: Springer Nature Switzerland.

[32] Ebrahim, A., Battilana, J., & Mair, J. (2014). The governance of social enterprises: Mission drift and accountability challenges in hybrid organizations. Research in organizational behavior, 34, 81-100.

[33] Elouataoui, W., El Alaoui, I., El Mendili, S., & Gahi, Y. (2022). An advanced big data quality framework based on weighted metrics. Big Data and Cognitive Computing, 6(4), 153.

[34] Filatotchev, I., Ireland, R. D., & Stahl, G. K. (2022). Contextualizing management research: An open systems perspective. Journal of Management Studies, 59(4), 1036-1056.

[35] Frota Barcellos, J. (2019). Critical Elements of a Successful Project.

[36] Gökalp, M. O., Gökalp, E., Kayabay, K., Koçyiğit, A., & Eren, P. E. (2021). Data-driven manufacturing: An assessment model for data science maturity. Journal of Manufacturing Systems, 60, 527-546.

[37] Grandhi, B., Patwa, N., & Saleem, K. (2021). Data-driven marketing for growth and profitability. EuroMed Journal of Business, 16(4), 381-398.

[38] Habibi, M., Kermanshachi, S., & Rouhanizadeh, B. (2019). Identifying and measuring engineering, procurement, and construction (EPC) key performance indicators and management strategies. Infrastructures, 4(2), 14.

[39] Hashem, I. A. T., Yaqoob, I., Anuar, N. B., Mokhtar, S., Gani, A., & Khan, S. U. (2015). The rise of "big data" on cloud computing: Review and open research issues. Information systems, 47, 98-115.

[40] Henke, N., & Jacques Bughin, L. (2016). The age of analytics: Competing in a data-driven world.

[41] Hossain, M. D. (2018). Performance evaluation of procurement system in ICT Industry a case study.

[42] Ibrahim, I. I. (2015). Project planning in construction procurement: the case of Nigerian indigenous contractors (Doctoral dissertation).

[43] Jones, C. L., Golanz, B., Draper, G. T., & Janusz, P. (2020). Practical Software and Systems Measurement Continuous Iterative Development Measurement Framework. Version, 1, 15.

[44] Jones, S. C. (2014). Impact & excellence: data-driven strategies for aligning mission, culture and performance in nonprofit and government organizations. John Wiley & Sons.

[45] Kabirifar, K., & Mojtahedi, M. (2019). The impact of engineering, procurement and construction (EPC) phases on project performance: a case of large-scale residential construction project. Buildings, 9(1), 15.

[46] Kayabay, K., Gökalp, M. O., Gökalp, E., Eren, P. E., & Koçyiğit, A. (2022). Data science roadmapping: An architectural framework for facilitating transformation towards a data-driven organization. Technological Forecasting and Social Change, 174, 121264.

[47] Laranjeiro, N., Soydemir, S. N., & Bernardino, J. (2015, November). A survey on data quality: classifying poor data. In 2015 IEEE 21st Pacific rim international symposium on dependable computing (PRDC) (pp. 179-188). IEEE.

[48] Liu, T., Wang, Y., & Wilkinson, S. (2016). Identifying critical factors affecting the effectiveness and efficiency of tendering processes in Public–Private Partnerships (PPPs): A comparative analysis of Australia and China. International Journal of project management, 34(4), 701-716.

[49] Maja, M. M., & Letaba, P. (2022). Towards a data-driven technology roadmap for the bank of the future: Exploring big data analytics to support technology roadmapping. Social Sciences & Humanities Open, 6(1), 100270.

[50] Micheli, G. J., & Cagno, E. (2016). The role of procurement in performance deviation recovery in large EPC projects. International journal of engineering business management, 8, 1847979016675302.

[51] Mohanty, S. P., Choppali, U., & Kougianos, E. (2016). Everything you wanted to know about smart cities: The Internet of things is the backbone. IEEE consumer electronics magazine, 5(3), 60-70.

[52] Moretto, A., Patrucco, A. S., Walker, H., & Ronchi, S. (2022). Procurement organisation in project-based setting: a multiple case study of engineer-to-order companies. Production planning & control, 33(9-10), 847-862.

[53] Navarro, L. F. M. (2017). Investigating the influence of data analytics on content lifecycle management for maximizing resource efficiency and audience impact. Journal of Computational Social Dynamics, 2(2), 1-22.

[54] Nguyen, H. T., & Hadikusumo, B. H. (2018). Human resource related factors and engineering, procurement, and construction (EPC) project success. Journal of Financial Management of Property and Construction, 23(1), 24-39.

[55] Ojebode, A., & Onekutu, P. (2021). Nigerian Mass Media and Cultural Status Inequalities: A Study among Minority Ethnic Groups. Technium Soc. Sci. J., 23, 732.

[56] Okpeh, O. O., & Ochefu, Y. A. (2010). The Idoma Ethnic group: A Historical and Cultural Setting. A Manuscript.

[57] Olufemi-Phillips, A. Q., Ofodile, O. C., Toromade, A. S., Eyo-Udo, N. L., & Adewale, T. T. (2020). Optimizing FMCG supply chain management with IoT and cloud computing integration. International Journal of Management & Entrepreneurship Research, 6(11). Fair East Publishers.

[58] Onukwulu, E. C., Agho, M. O., & Eyo-Udo, N. L. (2021). Framework for sustainable supply chain practices to reduce carbon footprint in energy. Open Access Research Journal of Science and Technology, 1(2), 012–034. https://doi.org/10.53022/oarjst.2021.1.2.0032

[59] Onukwulu, E. C., Agho, M. O., & Eyo-Udo, N. L. (2022). Advances in green logistics integration for sustainability in energy supply chains. World Journal of Advanced Science and Technology, 2(1), 047–068.https://doi.org/10.53346/wjast.2022.2.1.0040

[60] Onukwulu, E. C., Agho, M. O., & Eyo-Udo, N. L. (2022). Circular economy models for sustainable resource management in energy supply chains. World Journal of Advanced Science and Technology, 2(2), 034-057.https://doi.org/10.53346/wjast.2022.2.2.0048

[61] Onukwulu, N. E. C., Agho, N. M. O., & Eyo-Udo, N. N. L. (2021). Advances in smart warehousing solutions for optimizing energy sector supply chains. Open Access Research Journal of Multidisciplinary Studies, 2(1), 139-157. https://doi.org/10.53022/oarjms.2021.2.1.0045

[62] Ordanini, A., Parasuraman, A., & Rubera, G. (2014). When the recipe is more important than the ingredients: A qualitative comparative analysis (QCA) of service innovation configurations. Journal of service research, 17(2), 134-149.

[63] Osei-Kyei, R., & Chan, A. P. (2015). Review of studies on the Critical Success Factors for Public–Private Partnership (PPP) projects from 1990 to 2013. International journal of project management, 33(6), 1335-1346.

[64] Oyeniyi, L. D., Igwe, A. N., Ofodile, O. C., & Paul-Mikki, C. (2021). Optimizing risk management frameworks in banking: Strategies to enhance compliance and profitability amid regulatory challenges.

[65] Pace, M. L., Carpenter, S. R., & Cole, J. J. (2015). With and without warning: managing ecosystems in a changing world. Frontiers in Ecology and the Environment, 13(9), 460-467.

[66] Pal, R., Wang, P., & Liang, X. (2017). The critical factors in managing relationships in international engineering, procurement, and construction (IEPC) projects of Chinese organizations. International Journal of Project Management, 35(7), 1225-1237.

[67] Panda, D., & Sahu, G. P. (2014). E-procurement implementation: Comparative study of governments of Andhra Pradesh and Chhattisgarh. SSRN.

[68] Patel, A., Alhussian, H., Pedersen, J. M., Bounabat, B., Júnior, J. C., & Katsikas, S. (2017). A nifty collaborative intrusion detection and prevention architecture for smart grid ecosystems. Computers & Security, 64, 92-109.

[69] Peng, G., Privette, J. L., Kearns, E. J., Ritchey, N. A., & Ansari, S. (2015). A unified framework for measuring stewardship practices applied to digital environmental datasets. Data Science Journal, 13, 231-253.

[70] Pereira, M. M., & Frazzon, E. M. (2021). A data-driven approach to adaptive synchronization of demand and supply in omni-channel retail supply chains. International Journal of Information Management, 57, 102165.

[71] Pora, U., Gerdsri, N., Thawesaengskulthai, N., & Triukose, S. (2020). Data-driven roadmapping (DDRM): Approach and case demonstration. IEEE Transactions on Engineering Management, 69(1), 209-227.

[72] Pora, U., Thawesaengskulthai, N., Gerdsri, N., & Triukose, S. (2018, August). Data-driven roadmapping turning challenges into opportunities. In 2018 Portland International Conference on Management of Engineering and Technology (PICMET) (pp. 1-11). IEEE.

[73] Pulwarty, R. S., & Sivakumar, M. V. (2014). Information systems in a changing climate: Early warnings and drought risk management. Weather and Climate Extremes, 3, 14-21.

[74] Raza, H. (2021). Proactive Cyber Defense with AI: Enhancing Risk Assessment and Threat Detection in Cybersecurity Ecosystems.

[75] Ren, J., Guo, Y., Zhang, D., Liu, Q., & Zhang, Y. (2018). Distributed and efficient object detection in edge computing: Challenges and solutions. IEEE Network, 32(6), 137-143.

[76] Rico, R., Hinsz, V. B., Davison, R. B., & Salas, E. (2018). Structural influences upon coordination and performance in multiteam systems. Human Resource Management Review, 28(4), 332-346.

[77] Roden, S., Nucciarelli, A., Li, F., & Graham, G. (2017). Big data and the transformation of operations models: a framework and a new research agenda. Production Planning & Control, 28(11-12), 929-944.

[78] Rogers, K. (2020). Creating a Culture of Data-Driven Decision-Making. Liberty University.

[79] Ross, D. F., & Ross, D. F. (2015). Procurement and supplier management. Distribution planning and control: Managing in the era of supply chain management, 531-604.

[80] Roth, S., Valentinov, V., Kaivo-Oja, J., & Dana, L. P. (2018). Multifunctional organisation models: a systems–theoretical framework for new venture discovery and creation. Journal of Organizational Change Management, 31(7), 1383-1400.

[81] Saarikallio, M. (2022). Improving hybrid software business: quality culture, cycle-time and multi-team agile management. JYU dissertations.

[82] Saiod, A. K., Van Greunen, D., & Veldsman, A. (2017). Electronic health records: benefits and challenges for data quality. Handbook of Large-Scale Distributed Computing in Smart Healthcare, 123-156.

[83] Salamkar, M. A., & Allam, K. (2019). Data Lakes Vs. Data Warehouses: Comparative Analysis on When to Use Each, With Case Studies Illustrating Successful Implementations. Distributed Learning and Broad Applications in Scientific Research, 5.

[84] Sandilya, S. K., & Varghese, K. (2016). A study of delays in procurement of engineered equipment for engineering, procurement and construction (EPC) projects in India: a mixed method research approach.

[85] Santoni, G. (2019). Standardized cross-functional communication as a robust design tool-Mitigating variation, saving costs and reducing the New Product Development Process' lead time by optimizing the information flow (Doctoral dissertation, Politecnico di Torino).

[86] Sebastian, I. M., Ross, J. W., Beath, C., Mocker, M., Moloney, K. G., & Fonstad, N. O. (2020). How big old companies navigate digital transformation. In Strategic information management (pp. 133-150). Routledge.

[87] Shaw, T., McGregor, D., Brunner, M., Keep, M., Janssen, A., & Barnet, S. (2017). What is eHealth (6)? Development of a conceptual model for eHealth: qualitative study with key informants. Journal of medical Internet research, 19(10), e324.

[88] Siddiqa, A., Hashem, I. A. T., Yaqoob, I., Marjani, M., Shamshirband, S., Gani, A., & Nasaruddin, F. (2016). A survey of big data management: Taxonomy and state-of-the-art. Journal of Network and Computer Applications, 71, 151-166.

[89] Silwimba, S. (2019). An investigation into the effects of procurement methods on project delivery in the Zambian road sector (Doctoral dissertation, The University of Zambia).

[90] Singh, A. P. A., & Abhinav Parashar, A. (2021). Streamlining Purchase Requisitions and Orders: A Guide to Effective Goods Receipt Management. J. Emerg. Technol. Innov. Res, 8(5), g179-g184.

[91] Singh, A., & Chatterjee, K. (2017). Cloud security issues and challenges: A survey. Journal of Network and Computer Applications, 79, 88-115.

[92] Singh, S. P., Nayyar, A., Kumar, R., & Sharma, A. (2019). Fog computing: from architecture to edge computing and big data processing. The Journal of Supercomputing, 75, 2070-2105.

[93] Skelton, M., & Pais, M. (2019). Team topologies: organizing business and technology teams for fast flow. It Revolution.

[94] Soni, P., & T. Krishnan, R. (2014). Frugal innovation: aligning theory, practice, and public policy. Journal of Indian Business Research, 6(1), 29-47.

[95] Srivastava, A., Jawaid, S., Singh, R., Gehlot, A., Akram, S. V., Priyadarshi, N., & Khan, B. (2022). Imperative role of technology intervention and implementation for automation in the construction industry. Advances in Civil Engineering, 2022(1), 6716987.

[96] Steyn, M. (2014). Organisational benefits and implementation challenges of mandatory integrated reporting: Perspectives of senior executives at South African listed companies. Sustainability Accounting, Management and Policy Journal, 5(4), 476-503.

[97] Stone, M., Aravopoulou, E., Gerardi, G., Todeva, E., Weinzierl, L., Laughlin, P., & Stott, R. (2017). How platforms are transforming customer information management. The Bottom Line, 30(3), 216-235.

[98] Sturtevant, C., DeRego, E., Metzger, S., Ayres, E., Allen, D., Burlingame, T., ... & SanClements, M. (2022). A process approach to quality management doubles NEON sensor data quality. Methods in Ecology and Evolution, 13(9), 1849-1865.

[99] Sun, Y., Zhang, J., Xiong, Y., & Zhu, G. (2014). Data security and privacy in cloud computing. International Journal of Distributed Sensor Networks, 10(7), 190903.

[100] Syed, J., Mahmood, S. K. A., Zulfiqar, A., Sharif, M., Sethi, U. I., Ikram, U., & Afridi, S. K. (2020). The construction sector value chain in Pakistan and the sahiwal coal power project. China's Belt and Road Initiative in a Global Context: Volume II: The China Pakistan Economic Corridor and its Implications for Business, 271-287.

[101] Tang, P., Yilmaz, A., & Cooke, N. (2018). Automatic Imagery Data Analysis for Proactive Computer-Based Workflow Management during Nuclear Power Plant Outages (No. 15-8121). Arizona State Univ., Tempe, AZ (United States).

[102] Tariq, N., Asim, M., Al-Obeidat, F., Zubair Farooqi, M., Baker, T., Hammoudeh, M., & Ghafir, I. (2019). The security of big data in fog-enabled IoT applications including blockchain: A survey. Sensors, 19(8), 1788.

[103] Tezel, A., Papadonikolaki, E., Yitmen, I., & Hilletofth, P. (2020). Preparing construction supply chains for blockchain technology: An investigation of its potential and future directions. Frontiers of Engineering Management, 7, 547-563.

[104] Thamrin, D. A. F. (2017). Six Sigma Implementation and Integration within Project Management Framework in Engineering, Procurement, and Construction Projects-A Case Study in a Southeast Asian Engineering, Procurement, and Construction Company.

[105] Thumburu, S. K. R. (2020). Integrating SAP with EDI: Strategies and Insights. MZ Computing Journal, 1(1).

[106] Toutounchian, S., Abbaspour, M., Dana, T., & Abedi, Z. (2018). Design of a safety cost estimation parametric model in oil and gas engineering, procurement and construction contracts. Safety science, 106, 35-46.

[107] Tseng, M. L., Tran, T. P. T., Ha, H. M., Bui, T. D., & Lim, M. K. (2021). Sustainable industrial and operation engineering trends and challenges Toward Industry 4.0: A data driven analysis. Journal of Industrial and Production Engineering, 38(8), 581-598.

[108] Tuli, F. A., Varghese, A., & Ande, J. R. P. K. (2018). Data-Driven Decision Making: A Framework for Integrating Workforce Analytics and Predictive HR Metrics in Digitalized Environments. Global Disclosure of Economics and Business, 7(2), 109-122.

[109] Vallejo-Vaz, A. J., Akram, A., Seshasai, S. R. K., Cole, D., Watts, G. F., Hovingh, G. K., ... & EAS Familial Hypercholesterolaemia Studies Collaboration. (2016). Pooling and expanding registries of familial hypercholesterolaemia to assess gaps in care and improve disease management and outcomes: rationale and design of the global EAS Familial Hypercholesterolaemia Studies Collaboration. Atherosclerosis Supplements, 22, 1-32.

[110] Van Zyl, E. S., Mathafena, R. B., & Ras, J. (2017). The development of a talent management framework for the private sector. SA Journal of Human Resource Management, 15(1), 1-19.

[111] Vehviläinen, T. (2019). Improving process efficiency and supply chain management by taking advantage of digitalization-based procurement tools.

[112] Vilasini, N., Neitzert, T. R., & Rotimi, J. O. (2011). Correlation between construction procurement methods and lean principles. International journal of construction management, 11(4), 65-78.

[113] Vlietland, J., Van Solingen, R., & Van Vliet, H. (2016). Aligning codependent Scrum teams to enable fast business value delivery: A governance framework and set of intervention actions. Journal of Systems and Software, 113, 418-429.

[114] Watson, R., Wilson, H. N., Smart, P., & Macdonald, E. K. (2018). Harnessing difference: a capability-based framework for stakeholder engagement in environmental innovation. Journal of Product Innovation Management, 35(2), 254-279.

[115] Whitehead, J. (2017). Prioritizing sustainability indicators: Using materiality analysis to guide sustainability assessment and strategy. Business strategy and the environment, 26(3), 399-412.

[116] Yu, W., Dillon, T., Mostafa, F., Rahayu, W., & Liu, Y. (2019). A global manufacturing big data ecosystem for fault detection in predictive maintenance. IEEE Transactions on Industrial Informatics, 16(1), 183-192.

[117] Zhang, C., Tang, P., Cooke, N., Buchanan, V., Yilmaz, A., Germain, S. W. S., ... & Gupta, A. (2017). Human-centered automation for resilient nuclear power plant outage control. Automation in Construction, 82, 179-192.

[118] Zolnowski, A., Christiansen, T., & Gudat, J. (2016, June). Business Model Transformation Patterns of Data-Driven Innovations. In ECIS (Vol. 2016, p. 146).

[119] Zong, Z. (2022, December). KCL: A Declarative Language for Large-Scale Configuration and Policy Management. In Dependable Software Engineering. Theories, Tools, and Applications: 8th International Symposium, SETTA 2022, Beijing, China, October 27-29, 2022, Proceedings (Vol. 13649, p. 88). Springer Nature.

[120] Zou, M., Vogel-Heuser, B., Sollfrank, M., & Fischer, J. (2020, December). A cross-disciplinary model-based systems engineering workflow of automated production systems leveraging socio-technical aspects. In 2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 133-140). IEEE.