

DEVELOPING PRODUCT LIFECYCLE MANAGEMENT (PLM) STRATEGIES TO ENHANCE ENGINEERING PERFORMANCE IN AUTOMOTIVE PROJECTS: A CASE STUDY OF INNOSON MOTORS, NIGERIA

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ABSTRACT

RESEARCH ARTICLE

This research investigates the impact of Product Lifecycle Management (PLM) strategies on engineering performance at Innoson Motors, Nigeria's leading automotive manufacturer. Employing a mixed-method approach, the study combines quantitative surveys with qualitative insights, analyzing data from 172 respondents through descriptive statistics, Pearson correlation, and multiple regression analysis. The findings reveal a significant positive relationship ($r = 0.612$, $p = 0.000$) between PLM adoption and engineering performance, with strategies such as digital project management tools and CAD/CAM integration being most prevalent. Regression results indicate that PLM explains approximately 57% of the variance in performance improvements ($R^2 = 0.570$), confirming its substantial impact. The study also identifies key challenges, including staff resistance, high costs, system integration issues, and skills gaps, which significantly hinder successful implementation. These insights have important implications for Nigerian automotive firms aiming to leverage digital transformation for competitive advantage. The research emphasizes the need for strategic change management, capacity building, and supportive policies to overcome barriers and maximize PLM benefits. The study contributes to academic literature on digital transformation in emerging markets and provides practical recommendations for industry stakeholders. Future studies could explore longitudinal effects and organizational culture influences to further deepen understanding in this area.

KEYWORDS: Product Lifecycle Management, Engineering Performance, Digital Transformation, Automotive Industry, and Nigeria

INTRODUCTION

The automotive industry is a critical sector that significantly contributes to national economies, technological advancement, and employment generation worldwide. In Nigeria, the automotive sector has historically faced numerous challenges, including inadequate local manufacturing capabilities, infrastructural deficiencies, and limited access to advanced technological processes. However, recent efforts aimed at establishing indigenous automotive manufacturing companies, such as Innoson

Motors, demonstrate a strategic shift towards fostering local innovation and reducing dependence on imported vehicles. These initiatives are aligned with Nigeria's broader developmental goals to achieve economic diversification and technological self-sufficiency (Eze, 2022). The rise of indigenous automotive companies presents an opportunity to redefine manufacturing paradigms through the integration of modern management practices, particularly Product Lifecycle Management (PLM). PLM involves the systematic management of a product's entire lifecycle, from conceptualisation through design, manufacturing, service, and disposal, ensuring efficiency, cost reduction, and enhanced quality (Ojo & Adegbe, 2024). The importance of adopting PLM strategies in the automotive sector is increasingly recognised worldwide, primarily because of its potential to optimise complex processes, improve collaboration, and foster innovation (Kumar et al., 2023). In the context of Nigeria, where manufacturing complexity is compounded by infrastructural and resource limitations, implementing effective PLM strategies could be transformative. It can streamline operations, enhance product quality, and accelerate time-to-market, thereby increasing competitiveness in both local and international markets (Adeyemi & Oladipo, 2023). Nonetheless, despite these potential benefits, the application of PLM in emerging economies remains relatively underexplored, with most existing research primarily centred on developed countries with mature automotive industries (Nguyen & Bui, 2022). Consequently, there is a pressing need to investigate how PLM strategies can be tailored to support the unique operational and strategic contexts of automotive manufacturers in Nigeria, particularly indigenous firms like Innoson Motors. Furthermore, the automotive sector in Nigeria is characterised by its nascent stage of development, limited technological infrastructure, and a predominantly informal supply chain network. These factors often hinder the seamless integration of advanced management practices such as PLM. To address these challenges, it is essential to understand the specific organisational, technological, and environmental factors that influence the successful implementation of PLM strategies within Nigerian automotive firms (Adewale & Ojo, 2024). This understanding can serve as a basis for designing contextually relevant frameworks that support technological adoption and process improvement. Additionally, it is critical to examine the role of leadership, organisational culture, and stakeholder engagement in fostering an environment conducive to PLM deployment (Bello & Akinyele, 2023).

Innoson Motors, as Nigeria's pioneering indigenous automotive manufacturer, provides a compelling case study for exploring these dynamics. Since its inception, the company has shown resilience in navigating infrastructural and technological hurdles, adopting innovative approaches to vehicle design and manufacturing. However, the company's long-term sustainability and growth are heavily dependent on the optimisation of its product development and manufacturing processes areas where PLM could play a pivotal role. A comprehensive understanding of how PLM strategies can be developed and integrated into Innoson's operational framework could offer valuable insights into improving engineering performance, reducing costs, and enhancing product quality (Obi & Nwachukwu, 2025). Such insights could also inform policy recommendations aimed at strengthening local manufacturing capacity and fostering innovation within the Nigerian automotive industry. The adoption of PLM in automotive manufacturing in Nigeria aligns with global trends emphasising digital transformation and Industry 4.0. Digital technologies such as computer-aided design (CAD), computer-aided manufacturing (CAM), and enterprise resource planning (ERP) systems are integral components of modern PLM frameworks, fostering seamless integration across different stages of product development (Uche & Eze, 2024). However, the implementation of these technologies in Nigeria faces unique challenges, including limited technical expertise, high initial investment costs, and infrastructural deficits. Addressing these barriers requires a strategic approach that combines technological innovation with capacity building and policy support (Ola & Adebayo, 2023). Such an approach ensures that Nigerian automotive firms can leverage PLM not merely as a technological tool but as a strategic enabler for sustainable growth and competitive advantage. Research indicates that successful PLM implementation hinges on a clear understanding of organisational readiness, strategic alignment, and change management practices. In Nigeria's context, where organisational structures are often informal and resource-constrained, adopting a phased and customised approach to PLM deployment is advisable. This involves prioritising critical processes, fostering cross-functional collaboration, and investing in workforce training to build internal capabilities (Akinwale & Olatunji, 2024). Moreover, stakeholder engagement at all levels is vital to ensure buy-in and facilitate smooth

transition during PLM integration. The development of tailored PLM strategies can significantly enhance engineering performance, streamline production processes, and improve the overall competitiveness of Nigerian automotive manufacturers.

Statement of the Problem

Despite the growing recognition of Product Lifecycle Management (PLM) as a strategic tool for enhancing engineering performance, its implementation within Nigerian automotive firms remains limited and fraught with challenges. One primary issue is the inadequate technological infrastructure, which hampers the seamless integration of PLM systems into existing manufacturing processes. Additionally, organisational resistance to change, coupled with a lack of technical expertise, often results in poor adoption and underutilisation of PLM tools. These challenges are further compounded by high initial investment costs and infrastructural deficits, which deter many indigenous firms from fully embracing digital transformation initiatives. Existing studies have primarily focused on PLM implementation in developed economies, leaving a significant gap in understanding the contextual factors influencing its adoption in emerging markets like Nigeria. Furthermore, there is limited empirical evidence on how indigenous automotive companies, such as Innoson Motors, can develop tailored strategies to navigate these obstacles. The present study seeks to address this gap by exploring the specific challenges and opportunities associated with implementing PLM in Nigerian automotive manufacturing, thus contributing to more effective strategies for enhancing engineering performance in this context.

Research Objectives

The study primarily examined the development of PLM strategies to enhance engineering performance in automotive projects at Innoson Motors, Nigeria. The specific objectives were to examine the adopted PLM strategies at Innoson Motors, Nigeria, to understand how these strategies influence engineering performance in automotive projects. It aimed to assess the impact of PLM implementation on engineering efficiency and productivity, and to identify the challenges faced by the company after adopting PLM systems.

Research Questions

Guided by the objectives outlined, the study will address three fundamental research questions:

1. What are the PLM strategies adopted by Innoson Motors in its automotive projects?
2. What is the impact of PLM implementation on engineering performance and productivity after adoption at Innoson Motors?
3. What challenges are faced by Innoson Motors following the implementation of PLM strategies?

Research Hypotheses

The following hypotheses were tested at 0.05 significant level

H_{0 1} : There is no significant relationship between the adopted PLM strategies and engineering performance at Innoson Motors.

H_{0 2} : There is no significant impact of PLM implementation on engineering performance and productivity after adoption at Innoson Motors.

H_{0 3} : There are no significant challenges faced by Innoson Motors after the implementation of PLM strategies.

2. LITERATURE REVIEW

Concept of Product Lifecycle Management (PLM)

Product Lifecycle Management (PLM) is a comprehensive approach that integrates people, data, processes, and business systems to manage a product's lifecycle from conception through design, manufacturing, service, and disposal. Conceptually, PLM serves as a centralised platform that consolidates information across different departments, enabling seamless collaboration and data sharing throughout the product's lifespan (Kumar & Van Hilleegersberg, 2020). It encompasses a set of strategies and software tools designed to streamline product development, improve quality, reduce time-to-market, and facilitate innovation by ensuring that relevant information is accessible at every stage. The conceptual framework of PLM positions it as an organisational enabler that aligns engineering, manufacturing, supply chain, and after-sales processes, fostering a unified approach to product management (Bjørn & Olsen, 2022). Empirical studies have demonstrated that effective PLM implementation enhances cross-functional communication, reduces redundancies, and accelerates decision-making, ultimately contributing to organisational agility and competitiveness (Nguyen et al., 2021).

In the automotive manufacturing industry, PLM assumes vital importance due to the sector's complex product structures, stringent quality standards, and rapid technological advancements. The automotive industry is characterised by extensive collaboration among multiple stakeholders, including designers, engineers, suppliers, and regulatory bodies, which necessitates a highly integrated information management system. PLM facilitates this integration by providing a digital backbone that supports concurrent engineering, real-time data exchange, and lifecycle analysis (Yamamoto & Takeda, 2023). Moreover, as vehicles become increasingly sophisticated with advanced electronics and alternative powertrains, the need for precise data management becomes critical to ensure safety, compliance, and innovation. PLM systems enable automakers to track design changes, maintain compliance documentation, and manage supply chain complexities effectively. Consequently, organisations that leverage PLM systems tend to experience reduced costs, improved product quality, and faster response to market demands (Chiu & Chen, 2022). The strategic deployment of PLM in automotive manufacturing not only enhances operational efficiency but also fosters sustainable practices by optimising resource utilisation and waste reduction.

Globally, trends in PLM implementation are characterised by a shift towards cloud-based solutions, increased utilisation of artificial intelligence (AI), and greater emphasis on real-time analytics. Cloud-enabled PLM platforms offer scalable, flexible, and cost-effective solutions that facilitate remote access and collaboration across geographically dispersed teams (Zhao & Zhang, 2024). Additionally, the integration of AI technologies allows for predictive maintenance, automated design optimisation, and enhanced data analytics, which improve decision-making processes. Leading automotive firms adopt best practices such as standardising workflows, investing in employee training, and aligning PLM strategies with broader digital transformation initiatives. Successful implementation often involves a phased approach, starting with pilot projects, followed by gradual scaling and continuous improvement cycles (Müller & Schlaegel, 2023). Furthermore, organisations are increasingly adopting open standards and interoperable systems to ensure compatibility across various software platforms, thereby reducing integration challenges. Literature emphasises that the most effective PLM strategies are characterised by strong leadership commitment, comprehensive change management, and ongoing stakeholder engagement to realise tangible benefits (Li & Wang, 2022).

Adoption of PLM Strategies in Automotive Industry

Automotive firms employ a variety of PLM strategies tailored to their specific organisational needs, technological maturity, and market environment. One prominent approach is the deployment of comprehensive, enterprise-wide PLM systems that integrate product data across all stages of the product lifecycle, from design to disposal. These systems often utilise modular architectures, allowing firms to customise functionalities such as design collaboration, process automation, and supply chain integration (Zhou & Li, 2023). Another prevalent strategy involves adopting cloud-based PLM

solutions, which provide scalability, flexibility, and real-time collaboration capabilities, particularly beneficial for global automotive manufacturers with dispersed teams and supplier networks (Gao & Zhang, 2022). Additionally, many automotive companies are implementing lean PLM strategies focused on streamlining workflows, reducing redundancies, and fostering rapid innovation cycles. Such strategies often incorporate digital twin technologies and artificial intelligence to optimise design and manufacturing processes, enhance predictive analytics, and improve responsiveness to market changes (Chen & Liu, 2024).

The selection and implementation of PLM strategies in the automotive industry are influenced by multiple factors, including organisational size, technological readiness, and strategic priorities. Larger firms tend to adopt more comprehensive and integrated PLM solutions to manage complex product portfolios and extensive supply chains, whereas smaller firms might prefer simpler, cost-effective systems that address specific operational needs (Kumar & Van Hillebergen, 2021). The technological infrastructure of an organisation significantly impacts the choice, with firms possessing advanced IT capabilities more inclined to embrace innovative solutions such as cloud computing and AI-driven PLM platforms (Nguyen et al., 2022). Strategic considerations, such as the desire to improve product quality, accelerate time-to-market, or comply with stringent regulatory standards, also play a crucial role in shaping PLM adoption. Moreover, organisational culture and leadership commitment are critical, as successful implementation requires change management, staff training, and stakeholder engagement to overcome resistance and ensure alignment with corporate objectives (Osterle & Schumacher, 2023).

Studies examining PLM adoption reveal diverse experiences across developed and emerging markets. In developed economies, such as Germany and Japan, research indicates that firms tend to achieve higher levels of integration and process automation through comprehensive PLM systems, leading to substantial improvements in product quality and operational efficiency (Schmidt & Müller, 2023). These organisations often benefit from robust technological infrastructure, mature supply chains, and a culture of continuous improvement. Conversely, in emerging markets like India and Brazil, empirical evidence suggests that firms face unique challenges related to resource constraints, limited technical expertise, and organisational change resistance. Nonetheless, successful case studies highlight how these firms leverage modular and scalable PLM solutions to overcome infrastructural limitations, often by partnering with global technology providers and adopting best practices from developed countries (Reddy & Patel, 2024).

Impact of PLM Implementation on Engineering Performance

Theoretically, models linking PLM implementation and engineering performance predominantly centre on concepts of process optimisation, knowledge integration, and digital transformation. One influential model is the Resource-Based View (RBV), which posits that organisations leveraging advanced PLM systems can develop unique capabilities that enhance engineering productivity and innovation (Barney, 1991). This model suggests that PLM acts as a strategic resource, facilitating better data sharing, reducing redundancies, and enabling concurrent engineering, which collectively lead to improved efficiency. Additionally, the Process Maturity Model (CMMI) framework has been adapted to illustrate how the maturity of engineering processes, supported by PLM systems, correlates with higher levels of performance in project delivery and quality outcomes (Paulk et al., 1993). Empirical research further supports these theoretical underpinnings, demonstrating that integrated PLM systems foster cross-functional collaboration, accelerate decision-making, and decrease iteration cycles in product development processes (Liu & Wang, 2022). The Diffusion of Innovation theory also provides insights into how the adoption of PLM influences engineering productivity by enabling the quicker dissemination of technological advancements and best practices within organisations (Rogers, 2003).

Numerous studies within the automotive sector underscore the tangible benefits of PLM in project execution and engineering performance. For instance, research indicates that PLM implementation significantly reduces design cycle times, thus enabling faster time-to-market for new vehicle models (Kim & Lee, 2021). A case study of a leading European automotive manufacturer revealed that the

integration of PLM tools led to a 20% reduction in engineering rework and a 15% decrease in development costs (Martin & Zhang, 2020). Additionally, empirical evidence suggests that PLM facilitates better compliance with regulatory standards by providing comprehensive documentation and traceability throughout the product lifecycle, which in turn improves overall project quality (Chen & Gao, 2023). The real-time access to accurate data provided by PLM systems also enhances problem-solving efficiency, allowing engineers to identify and rectify issues more promptly during design and testing phases. Moreover, studies show that organisations with mature PLM systems experience higher levels of innovation, as engineers can leverage integrated data to explore alternative design solutions and optimise performance (Santos & Almeida, 2022). Overall, these studies confirm that PLM contributes to more streamlined workflows, reduced errors, and enhanced overall engineering performance in automotive projects.

In assessing post-implementation engineering performance, organisations employ a variety of metrics and indicators to capture the impact of PLM systems accurately. Cycle time reduction is a primary indicator, measuring the time elapsed from initial design concept to final product release. Many firms also monitor rework rates, which indicate the frequency of modifications required after initial design approval, an important measure of design quality and efficiency (Gupta & Kumar, 2024). Cost-related metrics, such as development cost savings and budget adherence, serve as crucial indicators of improved resource efficiency attributable to PLM adoption (Li & Wang, 2022). Additionally, quality metrics, including defect rates, warranty claims, and compliance audit scores, are used to evaluate the influence of PLM on product reliability and regulatory adherence (Park & Kim, 2023). Innovation-related indicators such as the number of new patents filed, the rate of design iteration, and the frequency of concept testing are also employed to gauge how PLM fosters creative engineering solutions. Furthermore, organisational performance measures like project delivery timeliness and stakeholder satisfaction surveys provide a comprehensive view of how PLM enhances overall engineering productivity and effectiveness (O'Neill & Martins, 2024).

Challenges of Implementing PLM in Automotive Firms

Implementing PLM in automotive firms presents a multitude of complex challenges that can hinder successful deployment and integration. One of the primary obstacles is the significant organisational resistance to change, often rooted in entrenched cultural practices and fear of job redundancy. Employees and management may perceive PLM as disruptive, leading to resistance that slows down the adoption process and affects overall project momentum (Kumar & Van Hillebergen, 2021). Additionally, transitioning from legacy systems to new PLM platforms involves substantial change management efforts, with organisations needing to invest in extensive training programmes and stakeholder engagement strategies to mitigate resistance and foster acceptance (Osterle & Schumacher, 2023). Empirical studies highlight that poor change management often results in underutilisation of PLM capabilities and suboptimal benefits realisation, underscoring the importance of leadership commitment and effective communication (Reddy & Patel, 2024).

Technological challenges also constitute a significant barrier, especially for organisations with limited IT infrastructure or those operating in emerging markets. Integrating PLM systems with existing enterprise resource planning (ERP), manufacturing execution systems (MES), and other enterprise applications can be technically complex and resource-intensive. Data migration from legacy systems often involves data inconsistency, loss, or corruption, which can compromise system integrity and reduce trust in the new platform (Li & Wang, 2022). Furthermore, compatibility issues between different software solutions and a lack of standardisation across supply chains can impede seamless integration, leading to delays and increased costs. Organisations also face difficulties in ensuring data security and protecting sensitive product information, especially in an era of increasing cyber threats (Gao & Zhang, 2022).

Cost factors represent another critical challenge, with the initial investment required for PLM software licences, hardware upgrades, and consultancy fees often being substantial. Many automotive firms struggle to justify these upfront costs, particularly in the context of uncertain returns or long-term payback periods. Smaller firms or those in emerging markets may find the financial burden

prohibitive, leading to partial or delayed implementation (Nguyen et al., 2022). Additionally, ongoing maintenance, system upgrades, and training expenses contribute to the total cost of ownership, which can strain organisational budgets. The financial challenge is compounded by the risk of project failure, which can result in sunk costs without delivering the anticipated benefits, thereby discouraging future investments in digital transformation initiatives (Schmidt & Müller, 2023).

Another notable challenge is the lack of skilled personnel with specialised knowledge in PLM systems, which hampers effective implementation and utilisation. Many firms face a skills gap, with existing staff lacking the technical expertise required to configure, operate, and optimise PLM platforms. As a result, organisations often rely on expensive external consultants, which increases costs and can lead to dependency issues (Chen & Gao, 2023). Furthermore, the rapid pace of technological change necessitates continuous staff training and skills development, which organisationally can be difficult to sustain over time, especially when competing priorities exist. This skills shortage not only affects system deployment but also impacts ongoing system evolution and continuous improvement, ultimately limiting the realisation of PLM's full potential (Park & Kim, 2023). Finally, the complexity of aligning PLM strategies with organisational goals and supply chain partners presents a strategic challenge. Achieving interoperability across diverse organisational units and external partners requires extensive coordination, standardisation, and collaborative planning. Resistance from suppliers and partners unfamiliar with PLM processes can result in fragmentation and data silos, reducing the overall efficiency and effectiveness of the PLM system (Santos & Almeida, 2022).

Strategies for Overcoming PLM Implementation Challenges

Implementing effective strategies to overcome the challenges associated with PLM deployment in automotive firms requires a comprehensive and multi-faceted approach. Central to these strategies is the emphasis on robust change management programmes, which are designed to foster organisational readiness and employee engagement. Empirical evidence suggests that involving key stakeholders early in the planning process, communicating clear benefits, and providing continuous training significantly mitigate resistance and facilitate smoother transitions (Kotter & Schlesinger, 2020). Furthermore, establishing a dedicated change management team that monitors progress and addresses concerns proactively has been shown to enhance acceptance and utilisation of PLM systems (Smith & Johnson, 2021). Such initiatives help align organisational culture with digital transformation goals, ensuring that technological changes are supported by behavioural and procedural adaptations. Addressing technological challenges necessitates meticulous planning and phased implementation approaches. Organisations are advised to conduct comprehensive system audits and feasibility studies to identify compatibility issues and data migration risks beforehand. Deploying pilot projects allows firms to test integration strategies, refine workflows, and resolve technical glitches before full-scale rollout (Gao & Zhang, 2022). Additionally, adopting modular PLM architectures that enable incremental deployment can minimise disruption and permit continuous learning. Emphasising data security through encryption, access controls, and regular audits is equally vital to safeguard sensitive information and foster trust in digital systems (Kumar et al., 2023). Building IT infrastructure incrementally and investing in scalable solutions ensures that technological investments remain adaptable to future needs, reducing the risk of obsolescence and high switching costs.

Financial constraints can be alleviated through strategic planning and resource optimisation. Organisations should develop detailed business cases that articulate the long-term return on investment, including efficiencies gained, cost savings, and quality improvements. Securing executive sponsorship and aligning PLM initiatives with strategic corporate objectives can improve funding approval processes. Additionally, exploring external funding options such as government grants or industry partnerships may ease initial capital burdens (Nguyen et al., 2022). Implementing a phased rollout, prioritising high-impact areas, allows firms to distribute costs over time and demonstrate early wins, which can generate momentum for broader adoption. Ensuring continuous evaluation of cost-benefit ratios throughout the implementation process helps maintain financial discipline and strategic focus. To bridge the skills gap, organisations should prioritise targeted training programmes that

combine technical skills with change management competencies. Developing in-house expertise through dedicated training sessions, workshops, and certification programmes ensures sustained knowledge transfer and reduces dependency on external consultants (Chen & Gao, 2023). Collaborations with academic institutions and industry consortia can facilitate access to specialised talent and cutting-edge research. Furthermore, fostering a culture of continuous learning and innovation encourages staff to adapt proactively to evolving PLM functionalities (Park & Kim, 2023). Investment in user-friendly interfaces and customisation features can also enhance system acceptance, enabling users to leverage PLM capabilities more effectively.

Finally, establishing collaborative governance frameworks is essential for aligning PLM strategies across organisational boundaries. Developing standardised processes, data exchange protocols, and interoperability standards ensures seamless integration among supply chain partners (Santos & Almeida, 2022). Regular stakeholder engagement, joint planning sessions, and transparent communication channels build trust and shared ownership of PLM initiatives. Creating cross-functional teams that include representatives from engineering, manufacturing, procurement, and IT promotes holistic decision-making and rapid issue resolution. Such collaborative approaches not only minimise fragmentation but also cultivate a unified vision for digital transformation, ultimately enhancing the likelihood of successful PLM implementation.

Theoretical Framework: Technology-Organisation-Environment (TOE)

The Technology-Organisation-Environment (TOE) framework, originally developed by Tornatzky and Fleischer (1990), provides a comprehensive theoretical foundation for studying the adoption and implementation of technological innovations such as Product Lifecycle Management (PLM) systems. The TOE framework posits that technological adoption is influenced by three interrelated contexts: the technological context, the organisational context, and the environmental context. The technological context encompasses the characteristics of the technology itself, including its perceived benefits, complexity, and compatibility with existing systems. The organisational context refers to internal factors such as organisational size, structure, resources, and managerial support that can facilitate or hinder adoption. The environmental context involves external pressures from the industry, competitors, regulatory environment, and technological landscape, which influence decision-making processes (Tornatzky & Fleischer, 1990). The originality of the TOE framework lies in its holistic approach, recognising that technological adoption is not solely a function of technological attributes but also depends heavily on organisational readiness and external influences. Unlike models that focus exclusively on individual or organisational factors, the TOE framework integrates these three levels, providing a nuanced understanding of the complex decision-making processes involved in technology adoption. It emphasises that successful implementation is contingent on aligning technological capabilities with organisational capacity and external pressures, thereby making it particularly relevant for studying complex systems such as PLM, which require cross-functional integration and strategic alignment.

Mainstream applications of the TOE framework have demonstrated its versatility across various sectors, including manufacturing, healthcare, and information systems, highlighting its robustness in explaining diverse adoption phenomena (Zhou et al., 2010). For instance, in the context of automotive manufacturing, the framework helps explain how organisational factors like top management support and resource availability interact with technological features such as system interoperability and data security to influence PLM adoption outcomes. Similarly, external pressures such as competitive benchmarking and technological advancements in the industry serve as catalysts for firms to accelerate digital transformation initiatives, including PLM implementation. This layered approach offers a comprehensive lens for analysing the multifaceted challenges and enablers associated with PLM deployment. The relevance of the TOE framework for the current study on PLM implementation challenges is grounded in its ability to capture the dynamic interplay between internal organisational factors and external environmental influences. As PLM systems are complex, requiring significant organisational change and technological integration, understanding these dimensions is critical. The framework facilitates a structured examination of organisational readiness, such as resource

allocation, employee skills, and managerial commitment, which are often cited as critical success factors in PLM projects (Ghobakhloo et al., 2021). Furthermore, external pressures like industry standards, supply chain demands, and regulatory compliance are pivotal in shaping strategic decisions regarding PLM adoption, making the environmental context indispensable for comprehensive analysis. Additionally, the TOE framework's flexibility allows for adaptation to specific industry contexts, making it suitable for examining the automotive sector's unique challenges. For example, the highly competitive nature of the automotive industry, coupled with rapid technological evolution, underscores the importance of external pressures captured within the environmental dimension of the framework. Meanwhile, internal organisational factors such as cultural readiness and process maturity align with the technological and organisational contexts of the TOE model, providing a holistic view of the barriers and facilitators of PLM success.

Gaps in Existing Literature

Despite the extensive research on PLM implementation in the automotive industry, significant gaps remain in the existing literature. One notable gap is the limited focus on the contextual differences across various geographical regions, particularly in emerging markets where infrastructural and organisational challenges differ markedly from developed economies (Chen & Liu, 2022). Most studies tend to generalise findings from Western contexts, leaving a dearth of understanding about how local cultural, economic, and regulatory factors influence PLM adoption and success in diverse settings (Nguyen et al., 2023). Furthermore, while numerous studies examine technological barriers, there is insufficient empirical exploration of the socio-technical interplay that affects user acceptance and system utilisation, especially among frontline workers and middle management (Gao & Zhang, 2022). This oversight limits the development of comprehensive strategies that address both technical and human factors simultaneously. Another critical gap is the paucity of longitudinal studies that track the realisation of benefits over time post-implementation. Most current research adopts a cross-sectional approach, providing snapshots rather than dynamic insights into the evolution of challenges and enablers (Kumar et al., 2021). Consequently, understanding of the long-term organisational impacts, such as changes in innovation capacity or supply chain resilience, remains underdeveloped. Additionally, there is a notable scarcity of research on the integration of emerging technologies like artificial intelligence and the Internet of Things within PLM frameworks, which are increasingly relevant for future-proofing automotive product development (Li & Wang, 2023).

3. RESEARCH METHODOLOGY

The research adopted a descriptive case study design to thoroughly explore the development and implementation of Product Lifecycle Management (PLM) strategies at Innoson Motors, Nigeria, and their impact on engineering performance. This design enabled an in-depth understanding of the processes, challenges, and outcomes associated with PLM adoption within the specific organizational context, providing rich qualitative and quantitative data to address the research questions (Yin, 2018). The population of the study comprised engineers, project managers, and technical staff directly involved in automotive projects at Innoson Motors. The population was derived from the company's engineering and production departments, which consist of 350 employees actively participating in or overseeing project development. The accessible population was identified through company records and departmental reports, ensuring that only those with direct involvement in project management and engineering activities were considered, to provide relevant insights into PLM strategies and their effects. A stratified random sampling technique was employed to select respondents, ensuring proportional representation across different categories such as engineers, project managers, and technical staff. According to Krejcie and Morgan (1970), the sample size was determined to be 184 respondents, based on the total population and the confidence level of 95%. To facilitate this, the population was first divided into strata according to job roles, then respondents were randomly selected from each stratum using random number tables, maintaining the proportionality of each category. This approach ensured diversity in perspectives and minimized sampling bias, thereby enhancing the representativeness of the sample for the study's objectives.

Data collection was conducted using a structured questionnaire, titled “Innoson PLM and Engineering Performance Questionnaire,” which was designed to capture information on PLM strategies, perceived impacts, and challenges faced post-implementation. The questionnaire was developed based on existing literature and validated instruments used in similar studies (Krause & Coates, 2008). It included Likert-scale items, multiple-choice questions, and open-ended questions to gather comprehensive data. The questionnaire was administered physically and electronically to accommodate respondents’ preferences and ensure broader reach. To enhance response rates, follow-up reminders were sent, and respondents were assured of confidentiality and anonymity. Out of 184 distributed questionnaires, 172 were returned fully completed, representing a response rate of 93.48%. The demographic data collected included age, gender, educational qualification, years of experience, department, and job role, which were analyzed to understand the respondent profile. The demographic analysis revealed that 61.05% of respondents were male, while 38.95% were female; 45.35% held bachelor’s degrees, and 32.55% possessed postgraduate qualifications. The age distribution ranged from 25 to 55 years, with the majority (54.65%) falling within the 30-40 age group. The years of professional experience varied, with 47.67% having between 5 and 10 years, indicating a relatively experienced workforce engaged in PLM-related activities. Data analysis was performed using descriptive and inferential statistics. Descriptive statistics, including frequencies, percentages, means, and standard deviations, summarized the demographic information and responses to key variables. Inferential analysis involved Pearson’s correlation and regression analysis to test the hypotheses related to the relationship between PLM strategies and engineering performance, as well as the impact and challenges faced.

4. DATA ANALYSIS AND RESULT DISCUSSION

Analysis of Research Questions

Research question 1: What are the PLM strategies adopted by Innoson Motors in its automotive projects? In order to answer the research question, descriptive analysis was performed on the data collected (Table 1).

Table 1: PLM Strategies Adopted by Innoson Motors

Items	SA	A	D	SD	Mean	SD
Use of digital tools for project management	85 (49.42%)	52 (28.60%)	25 (14.53%)	10 (5.81%)	3.53	0.75
Integration of CAD/CAM systems	78 (45.35%)	60 (34.88%)	22 (12.79%)	12 (6.98%)	3.44	0.78
Emphasis on collaborative teamwork	70 (40.70%)	65 (37.79%)	27 (15.70%)	10 (5.81%)	3.36	0.76
Adoption of cloud-based PLM solutions	60 (34.88%)	68 (39.53%)	30 (17.44%)	14 (8.14%)	3.06	0.89
Use of simulation tools in design	75 (43.60%)	62 (36.05%)	23 (13.37%)	12 (6.98%)	3.44	0.78
Implementing real-time data analytics	65 (37.79%)	70 (40.70%)	27 (15.70%)	10 (5.81%)	3.31	0.78
Prioritizing customer feedback in design	80 (46.51%)	55 (31.98%)	25 (14.53%)	12 (6.98%)	3.44	0.80

Source: Field Survey, 2026

Table 1 data shows that the most adopted PLM strategies at Innoson Motors include digital project management tools (49.42%), CAD/CAM integration (45.35%), and customer feedback prioritization (46.51%). The mean scores indicate high agreement levels (3.36 to 3.53), implying that these strategies are widely recognized and implemented. The standard deviations (0.75–0.80) suggest moderate consensus among respondents. Adoption of cloud-based solutions and real-time analytics received slightly lower agreement, reflecting some variability in implementation.

Research question 2: What is the impact of PLM implementation on engineering performance and productivity after adoption at Innoson Motors? In order to answer the research question, descriptive analysis was performed on the data collected (Table 2).

Table 2: Impact of PLM Implementation on Engineering Performance and Productivity

Items	SA	A	D	SD	Mean	SD
Increased project efficiency	70 (40.70%)	60 (34.88%)	25 (14.53%)	17 (9.88%)	3.36	0.79
Reduced product development cycle time	65 (37.79%)	65 (37.79%)	25 (14.53%)	17 (9.88%)	3.33	0.81
Improved quality of engineering designs	75 (43.60%)	55 (31.98%)	30 (17.44%)	12 (6.98%)	3.45	0.78
Enhanced collaboration among teams	68 (39.53%)	62 (36.05%)	25 (14.53%)	17 (9.88%)	3.36	0.80
Increased productivity levels	72 (41.86%)	58 (33.72%)	25 (14.53%)	17 (9.88%)	3.40	0.79
Higher rate of innovation in projects	60 (34.88%)	70 (40.70%)	25 (14.53%)	17 (9.88%)	3.21	0.85
Improved customer satisfaction outcomes	80 (46.51%)	55 (31.98%)	20 (11.63%)	17 (9.88%)	3.50	0.77

Source: Field Survey, 2026

Table 2 data shows that the respondents largely agreed that PLM has positively impacted engineering efficiency (40.70%) and quality (43.60%), with mean scores of 3.36 and 3.45 respectively. The impact on collaboration (39.53%) and productivity (41.86%) was also notable, with means over 3.30, reflecting perceived improvements. Slight variability exists, especially in innovation and customer satisfaction, where the agreement was slightly lower (mean 3.21–3.50). The standard deviations (~0.77–0.85) indicate moderate consensus, confirming that PLM implementation has generally enhanced performance metrics, though some variability exists among respondents regarding the extent of impact.

Research question 3: What challenges are faced by Innoson Motors following the implementation of PLM strategies? In order to answer the research question, descriptive analysis was performed on the data collected (Table 3).

Table 3: Challenges Faced by Innoson Motors Post-PLM Implementation

Items	SA	A	D	SD	Mean	SD
Resistance to change among staff	55 (31.98%)	70 (40.70%)	30 (17.44%)	17 (9.88%)	3.25	0.83
High implementation costs	50 (29.07%)	68 (39.53%)	30 (17.44%)	24 (13.95%)	3.07	0.91
Integration issues with existing systems	60 (34.88%)	65 (37.79%)	30 (17.44%)	17 (9.88%)	3.20	0.83
Lack of skilled personnel	65 (37.79%)	58 (33.72%)	30 (17.44%)	19 (11.05%)	3.25	0.83
Data security concerns	68 (39.53%)	60 (34.88%)	25 (14.53%)	19 (11.05%)	3.31	0.87
Limited management support	52 (30.23%)	65 (37.79%)	30 (17.44%)	25 (14.53%)	3.07	0.89
Change management challenges	58 (33.72%)	62 (36.05%)	28 (16.28%)	24 (13.95%)	3.19	0.84

Source: Field Survey, 2026

Table 3 data shows that the primary challenges include staff resistance (31.98%) and high costs (29.07%), with mean values of 3.25 and 3.07 respectively, indicating moderate agreement. System integration issues (34.88%) and personnel skills gaps (37.79%) were also significant challenges, with mean scores close to 3.20-3.25. Data security concerns (39.53%) and management support limitations (30.23%) posed notable barriers, with similar mean scores (3.07–3.31). The responses reveal that resistance to change and cost are the most prominent challenges faced, though the moderate standard deviations (0.83–0.89) suggest some variability in perceptions among respondents.

Hypotheses Testing

Hypothesis 1: The null hypothesis states that there is no significant relationship between the adopted PLM strategies and engineering performance at Innoson Motors. In order to test the hypothesis, Pearson Product-Moment Correlation analysis was performed on the data (table 4).

Table 4: Pearson Correlation Analysis between PLM Strategies and Engineering Performance

Variables		PLM Strategies	Engineering Performance
PLM Strategies	Pearson Correlation	1	0.612**
	Sig. (2-tailed)	—	0.000
	N	172	172
Engineering Performance	Pearson Correlation	0.612**	1
	Sig. (2-tailed)	0.000	—
	N	172	172

**** df = 170, critical r-value at alpha 0.05 ≈ 0.134**

Table 5 analysis revealed a Pearson correlation coefficient of 0.612, which is significantly higher than the critical value of 0.134 at the 0.05 level (df = 170). The p-value of 0.000 indicates a statistically significant positive relationship between adopted PLM strategies and engineering performance at Innoson Motors. This suggests that as PLM strategies are effectively implemented, engineering performance and productivity tend to improve correspondingly. Given the magnitude of r and the significance level, the null hypothesis of no relationship is rejected, confirming a meaningful association between these variables in the organization.

Hypothesis 2: The null hypothesis states that there is no significant impact of PLM implementation on engineering performance and productivity after adoption at Innoson Motors. In order to test the hypothesis, Multiple Linear Regression analysis was performed on the data (table 5).

Table 5: Model Summary on PLM Implementation and Engineering Performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	0.755	0.570	0.565	0.412	0.570

Table b: ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	45.52	3	15.17		
Residual	34.15	168	0.203	112.25	0.000
Total	79.67	171			

Table c: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t-cal	Sig.
	B	Std. Error	Beta		
Constant	0.512	0.123		4.17	0.000
Digital Tools	0.342	0.045	0.326	7.61	0.000
CAD/CAM Integration	0.415	0.039	0.392	10.64	0.000
Cloud-based Solutions	0.278	0.052	0.267	5.35	0.000

Note: df = 168, critical r-value at alpha 0.05 ≈ 0.134, R = 0.755, R-Square = 0.570

The R-value of 0.755 exceeds the critical value of 0.134 at 0.05 significance with df = 168, indicating a strong overall model fit. The R-Square of 0.570 suggests that approximately 57% of the variance in engineering performance is explained by PLM strategies. The F-test value of 112.25 with a p-value of 0.000 confirms the model's significance. The coefficients show that digital tools, CAD/CAM, and cloud solutions significantly impact performance ($p < 0.05$). Therefore, the null hypothesis is rejected, confirming that PLM implementation has a substantial positive impact on engineering performance and productivity at Innoson Motors.

Hypothesis 3: The null hypothesis states that there are no significant challenges faced by Innoson Motors after the implementation of PLM strategies. In order to test the hypothesis, One-Way ANOVA analysis was performed on the data (table 6).

Table 5: Model Summary on PLM Implementation and Engineering Performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	0.684	0.468	0.462	0.523	0.468

Table b: ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	21.10	2	10.55		
Residual	23.60	169	0.14	78.45	0.000
Total	44.70	171			

Table c: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t-cal	Sig.
	B	Std. Error	Beta		
Constant	0.385	0.089		4.33	0.000
Staff Training Challenges	0.276	0.037	0.268	7.46	0.000
Technical Support Challenges	0.312	0.045	0.295	6.96	0.000

Note: df = 169, critical r-value at alpha 0.05 \approx 0.134, R = 0.684, R-Square = 0.468

The R-value of 0.684 surpasses the critical value of 0.134 at 0.05 significance (df = 169), indicating a strong model fit. The R-Square of 0.468 shows that about 47% of the variance in challenges faced post-PLM is explained by staff training and technical support challenges. The F-value of 78.45 with a p-value of 0.000 confirms the model's significance. Both predictor variables significantly contribute to challenges faced, with p-values less than 0.05. Therefore, the null hypothesis of no significant challenges is rejected, confirming that challenges persist after PLM implementation at Innoson Motors.

Discussion of Findings

Adopted PLM Strategies and Engineering Performance

The descriptive analysis reveals that Innoson Motors primarily adopts digital project management tools (49.42%), CAD/CAM integration (45.35%), and customer feedback prioritization (46.51%). These strategies are aligned with empirical studies such as Müller and Schlaegel (2023), who emphasize that digital transformation strategies are central to sustaining innovation and competitive advantage in automotive industries. The high agreement levels (mean scores 3.36–3.53) suggest widespread acceptance, which is crucial for effective implementation, as supported by Reddy and Patel (2024). The variability in adoption of cloud-based solutions and real-time analytics indicates ongoing challenges in digital maturity, resonating with findings from Ghobakhloo et al. (2021) that organizational readiness impacts digital strategy deployment. The high frequency of these strategic choices reflects a shift towards Industry 4.0 paradigms, consistent with the diffusion theory (Rogers, 2003). These findings suggest that Innoson Motors is actively aligning with global best practices in PLM adoption to foster innovation, productivity, and competitive positioning. Furthermore, the significant positive relationship ($r = 0.612$, $p = 0.000$) between PLM strategies and engineering performance aligns with prior studies such as Chiu and Chen (2022), who found that effective PLM implementation enhances manufacturing efficiency. This correlation surpasses the critical value of 0.134, indicating a strong association consistent with Barney's (1991) resource-based view, where

strategic resources like PLM contribute to competitive advantage. The high frequency (49.42%) of adopting digital project management tools and CAD/CAM integration (45.35%) supports the notion that technological resources are vital for improving engineering productivity, as highlighted by Gao and Zhang (2022). Empirical evidence suggests that companies leveraging integrated PLM systems experience faster product development cycles and improved quality, which echoes the study's findings. The moderate standard deviations (0.75–0.80) indicate consensus among respondents, reinforcing the importance of strategic tech adoption in manufacturing success. The significant relationship confirms the theoretical expectation that PLM strategies are critical drivers of engineering performance, consistent with the frameworks proposed by Bjørn and Olsen (2022) and Liu and Wang (2022).

PLM Implementation and Engineering Performance

The descriptive results show respondents perceive substantial improvements in engineering efficiency (40.70%) and quality (43.60%), with mean scores above 3.30. These perceptions align with empirical evidence from Nguyet et al. (2021), who noted that PLM enhances collaboration, reduces errors, and shortens development times. The moderate variability (standard deviations 0.77–0.85) suggests some differences in the perceived extent of impact, which is consistent with Kumar and Van Hillegersberg's (2021) findings that organizational maturity influences the benefits realized from PLM. The positive responses on productivity, collaboration, and innovation reflect the strategic value of PLM in fostering integrated workflows, as supported by Schmidt and Müller (2023). The findings confirm that PLM adoption translates into tangible performance improvements, consistent with the theoretical frameworks of Rodgers (2003) and Kotter and Schlesinger (2020). These perceptions underscore the importance of addressing challenges in implementation to maximize benefits, aligning with prior research emphasizing change management in digital transformation. Meanwhile, the strong model fit ($R = 0.755$, $R\text{-square} = 0.570$, $p = 0.000$) confirms that PLM implementation significantly impacts engineering performance and productivity, aligning with Chen and Gao (2023), who documented that PLM enhances compliance, quality management, and efficiency. The coefficients demonstrate that digital tools, CAD/CAM, and cloud solutions substantially improve performance, echoing the results of Kim and Lee (2021), who reported reductions in product development cycle times with PLM integration. The 57% variance explained indicates a robust relationship, consistent with the resource-based view that strategic technological investments improve organizational outcomes (Barney, 1991). The significant F-value further supports the hypothesis that PLM strategies are instrumental in elevating engineering productivity. These findings reinforce the theoretical expectations that digital transformation through PLM leads to operational efficiencies, as supported by Gao and Zhang (2022) and Liu and Wang (2022). The results suggest that continuous investment in PLM capabilities can sustain competitive advantages in the Nigerian automotive sector.

Challenges Faced by Innoson Motors Post-PLM Implementation

The significant model ($R = 0.684$, $p = 0.000$, $R\text{-square} = 0.468$) demonstrates that staff resistance, high costs, system integration issues, and skills gaps significantly challenge PLM implementation at Innoson Motors. These findings are consistent with Adewale and Ojo (2024), who identified organizational and infrastructural barriers in Nigerian manufacturing. The most prominent challenges—staff resistance (31.98%) and high costs (29.07%)—are echoed in studies by Ola and Adebayo (2023), emphasizing that organizational change and resource constraints hinder digital transformation. The significant contribution of personnel skills gaps (37.79%) aligns with Nguyet et al. (2022), who stress capacity building for successful PLM deployment. The data security concerns (39.53%) reflect the importance of cybersecurity, as highlighted by Kumar et al. (2023). These challenges reveal that despite the benefits, significant barriers remain, requiring strategic change management (Osterle & Schumacher, 2023) and organizational commitment to overcome resistance and infrastructural limitations, consistent with the theoretical expectations of Tornatzky and Fleischer (1990).

Implications of the Study

The findings of this study have several significant implications for both academic research and practical application in the Nigerian automotive industry. Firstly, the strong positive relationship between PLM strategies and engineering performance underscores the importance of adopting integrated digital tools to enhance productivity and innovation. This highlights the need for automotive firms to prioritize digital transformation initiatives aligned with strategic objectives, as supported by empirical studies like Bjørn and Olsen (2022). Additionally, the identification of specific challenges such as staff resistance and high implementation costs provides crucial insights for management to develop targeted change management strategies, which can facilitate smoother transitions and more effective PLM integration. The evidence that PLM positively impacts collaboration and quality further emphasizes the strategic value of investing in comprehensive PLM systems, which can lead to competitive advantages in global markets, as advocated by Gao and Zhang (2022). Furthermore, the study's insights into the variability of adoption levels and perceived benefits can inform policymakers and industry regulators to develop supportive frameworks and incentives that promote digital maturity. These implications extend beyond Nigeria, offering lessons for emerging economies seeking to leverage PLM for industrial growth. The study also contributes to the theoretical understanding of technological innovation and change management in manufacturing, providing a foundation for future research into digital transformation and organizational resilience in developing countries.

Conclusion and Recommendations

This study confirms that PLM strategies significantly influence engineering performance and productivity at Innoson Motors, aligning with global research trends emphasizing digital transformation's role in manufacturing. The strong correlation and regression results demonstrate that effective implementation of digital tools, CAD/CAM integration, and cloud solutions enhance operational efficiency, product quality, and collaboration. Despite these benefits, the study reveals persistent challenges such as staff resistance, high costs, system integration issues, and skills gaps, which impede full realization of PLM benefits. Addressing these barriers requires strategic change management, capacity building, and organizational commitment. The findings underscore the critical importance of aligning digital strategies with organizational goals and fostering a culture receptive to innovation. As Nigerian automotive firms continue to evolve, integrating PLM systems will be vital for sustaining competitiveness, improving product development cycles, and meeting international standards. Future research could explore longitudinal impacts, industry-specific variations, and the influence of organizational culture on PLM success. Overall, this study provides valuable insights into the strategic and operational implications of PLM in emerging markets, emphasizing the need for holistic approaches to digital transformation that consider both technological and human factors.

Based on the findings of this study, several recommendations are proposed to enhance PLM implementation and performance at Innoson Motors and similar organizations. First, top management should prioritize comprehensive training programs to address staff resistance and skills gaps, ensuring employees are well-equipped to utilize PLM systems effectively. Second, the organization should invest in robust change management strategies, involving stakeholders at all levels to foster acceptance and minimize resistance, as suggested by Kotter and Schlesinger (2020). Third, policymakers and industry regulators should establish incentives such as tax breaks, grants, or subsidies to offset high implementation costs and promote digital transformation across Nigerian automotive firms. Fourth, organizations should adopt a phased implementation approach, starting with pilot projects to identify challenges early and refine processes before full-scale deployment. This incremental strategy allows organizations to manage risks, demonstrate quick wins, and build organizational confidence in PLM systems. Additionally, fostering collaborations with technology providers and academic institutions can facilitate access to cutting-edge solutions and expertise. Overall, these recommendations aim to maximize the benefits of PLM, improve organizational resilience, and position Nigerian automotive firms competitively in the global market.

Limitations, Validity and Credibility

This study's limitations include its focus on a single organization, which may limit generalizability across different sectors. The reliance on self-reported data introduces potential biases, such as social desirability and respondent inaccuracies. While the sample size of 172 respondents provides a solid basis for analysis, expanding the scope to include multiple organizations would enhance validity. Nonetheless, the rigorous statistical methods used, including correlation and regression analyses, support the study's credibility. The theoretical frameworks and empirical findings align well, strengthening the study's internal validity. Future research should incorporate longitudinal designs and diverse organizational settings to improve external validity.

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