

## **A Conceptual Analysis of PLM Fundamentals, Implementation, and Customization Using the 3DEXPERIENCE Platform**

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### **Abstract**

Product Lifecycle Management (PLM) has become a foundational capability for organizations seeking to manage product information, processes, and collaboration across increasingly complex engineering and manufacturing environments. Early PLM systems primarily focused on controlling design data and documentation; however, evolving business demands, globalized operations, and accelerated product development cycles have exposed limitations in traditional, tool-centric PLM implementations. These challenges have driven a shift toward platform-based PLM solutions that emphasize data continuity, scalability, and cross-domain integration.

This paper presents a structured conceptual analysis of PLM, beginning with its fundamental principles and evolution, and extending to an examination of how these principles are realized within the 3DEXPERIENCE platform. The study discusses key characteristics of platform-based PLM, including unified data models, role-based collaboration, and lifecycle governance across multiple enterprise domains. In addition, the paper explores how configuration and customization capabilities within the platform enable organizations to adapt PLM functionalities to their specific business processes and industry requirements while maintaining system integrity and upgradeability. By linking PLM theory with platform-level implementation and extensibility, this work highlights the role of modern PLM platforms as digital backbones that support enterprise-wide collaboration and digital transformation initiatives.

**Keywords:** Product Lifecycle Management, Platform-Based PLM, 3DEXPERIENCE Platform, Digital Engineering, PLM Customization, Enterprise Collaboration, Product Data Management, Digital Transformation

## Related Work

Product Lifecycle Management (PLM) has been extensively studied as a strategic approach for managing product information and processes across the lifecycle. Early foundational work established PLM as a framework for integrating product data, processes, and organizational roles, emphasizing its importance in supporting lean product development and enterprise-wide coordination [1]. Subsequent studies further formalized PLM concepts by highlighting its role in managing product evolution and knowledge reuse throughout design, manufacturing, and service phases [2]. As PLM adoption increased across industries, research began to focus on implementation challenges and architectural considerations. Process-oriented frameworks were proposed to guide PLM deployment within complex organizational environments, emphasizing alignment between business processes and PLM system capabilities [3]. With the growing complexity of products and development environments, researchers highlighted the need for PLM systems to evolve beyond data repositories toward more integrated and intelligent lifecycle platforms [4].

Several studies examined the historical evolution of PLM and identified a gradual transition from engineering-centric data management systems to enterprise-wide lifecycle solutions [5]. Product information modeling frameworks were introduced to support interoperability and consistency of product definitions across lifecycle stages, addressing limitations of fragmented and tool-specific data representations [6]. These developments reinforced the view of PLM as a central coordinating layer within digital product development ecosystems [7]. As organizations pursued greater lifecycle integration, research began to emphasize PLM's expanding role in manufacturing and downstream processes. Studies explored how PLM supports coordination between engineering and production by governing bills of materials, change management, and process alignment [8]. The concept of closed-loop PLM further extended this perspective by incorporating feedback from product usage and operational data into lifecycle decision-making [9].

The emergence of cloud-based and service-oriented computing models influenced PLM research by introducing new architectural possibilities. Cloud manufacturing concepts demonstrated how distributed resources and services could be integrated to support scalable and collaborative manufacturing environments [10]. At the same time, studies on smart and connected products highlighted the growing importance of data continuity across physical and digital product representations [11]. With the rise of Industry 4.0, PLM research increasingly intersected with cyber-physical systems and smart manufacturing paradigms. Researchers examined how digital integration across engineering and production systems enables real-time monitoring, adaptability, and optimization of manufacturing processes [12]. The concept of servitization further emphasized the need for PLM systems to support extended product lifecycles that include service and performance-based business models [13].

Recent studies have focused on data-driven manufacturing and the role of digital platforms in enabling intelligent decision-making across the product lifecycle [14]. Smart manufacturing architectures have been proposed to integrate design, production, and operational data within unified digital environments [15]. Cyber-physical system architectures further reinforced the importance of platform-based approaches that support seamless interaction between physical assets and digital models [16]. Research on Industry 4.0 has also highlighted open challenges related to system interoperability, scalability, and governance, all of which directly impact PLM architectures [17]. From an enterprise perspective, digital transformation frameworks emphasize the role of integrated platforms in aligning technology, processes, and organizational strategy [18].

PLM maturity models have been introduced to assess organizational readiness and guide the progressive adoption of PLM capabilities [19]. These models underscore the importance of moving beyond basic data management toward integrated, lifecycle-oriented PLM implementations. In parallel, the concept of the digital twin has gained attention as a mechanism for linking product design data with operational behavior throughout the lifecycle [20]. Further work on digital twins has emphasized simulation and synchronization between physical products and their virtual counterparts, reinforcing the need for robust PLM platforms to manage these complex relationships [21]. Industry-oriented studies have explored how digital transformation initiatives reshape engineering and manufacturing practices, placing greater demands on PLM systems for flexibility and integration [22].

Big data analytics has also been identified as a key enabler for extracting value from lifecycle data managed within PLM environments, particularly in the context of sustainable and efficient manufacturing [23]. Research on digital twin-driven manufacturing further extends this direction by positioning PLM platforms as central enablers of data-driven lifecycle optimization [24]. Recent contributions have consolidated these ideas by presenting comprehensive frameworks for smart manufacturing and digital enterprise integration, emphasizing the need for scalable, extensible PLM platforms that support continuous evolution [25]. Collectively, existing literature demonstrates a clear progression toward platform-based PLM architectures while also revealing the need for further conceptual clarity on implementation and customization strategies—an area this paper aims to address.

## 1. Introduction

The increasing complexity of modern products, combined with shortened development cycles and globally distributed teams, has made the effective management of product information a critical challenge for engineering-driven organizations. Product data is no longer confined to design activities but extends across engineering, manufacturing, supply chain, quality, service, and end-of-life phases. Managing this information in a consistent, traceable, and collaborative manner is essential for maintaining product quality, regulatory compliance, and operational efficiency. Product Lifecycle Management (PLM) emerged as a systematic approach to address these challenges by providing a structured framework for managing product-related data and processes

throughout the entire lifecycle. Early PLM solutions primarily focused on controlling design data and documents, often serving as extensions of computer-aided design systems. While these solutions improved data organization and version control, they were typically limited in scope, rigid in configuration, and tightly coupled to specific tools or departments.

As organizations evolved toward more integrated and digitalized operating models, the limitations of traditional, tool-centric PLM systems became increasingly evident. The need for real-time collaboration, seamless integration across enterprise systems, and adaptability to diverse business processes exposed gaps in scalability and flexibility. These requirements have driven a transition toward platform-based PLM architectures, which position PLM as a central digital backbone rather than a standalone application. Platform-based PLM solutions emphasize a unified data model, cross-domain collaboration, and extensibility through configuration and integration mechanisms. By supporting multiple lifecycle domains within a single environment, such platforms enable continuity of product information from early concept development through manufacturing and downstream operations. This shift aligns closely with broader digital transformation initiatives, where data consistency, interoperability, and process transparency are key enablers of organizational agility.

Within this context, the 3DEXPERIENCE platform represents a platform-based approach to PLM that integrates product definition, lifecycle governance, and collaboration across engineering and manufacturing domains. Rather than prescribing fixed workflows or data structures, the platform provides configurable and customizable capabilities that allow organizations to adapt PLM implementations to their specific operational and industry requirements. The objective of this paper is to present a conceptual analysis of Product Lifecycle Management and examine how PLM principles are implemented within a platform-based architecture using the 3DEXPERIENCE platform as a reference. The paper further explores the role of customization and extensibility in enabling scalable and adaptable PLM solutions. By linking foundational PLM concepts with platform-level implementation and configuration, this work aims to provide insights into the evolving role of PLM as an enterprise-wide digital backbone.

## **2. Fundamentals of Product Lifecycle Management**

Product Lifecycle Management (PLM) is a strategic enterprise approach that enables organizations to manage product information, processes, and collaboration across the complete lifecycle of a product, from initial concept and design through manufacturing, operation, and eventual retirement. As modern products become increasingly complex and multidisciplinary, involving mechanical, electrical, and software components developed by globally distributed teams, the need for a structured and integrated management framework becomes critical. PLM addresses this challenge by providing a unified view of product definitions and lifecycle states, ensuring consistency, traceability, and controlled access to information across all stakeholders involved in product realization.

A central objective of PLM is to establish a controlled environment for product data and lifecycle governance. This includes capabilities such as version and configuration management, formal change control, and approval workflows that regulate how product definitions evolve over time. In addition to data control, PLM plays a key role in enabling cross-functional collaboration by connecting engineering, manufacturing, quality, procurement, and service functions within a common framework. Through lifecycle states, workflows, and role-based access mechanisms, PLM supports coordinated decision-making while maintaining accountability, compliance, and transparency throughout the product lifecycle.

The evolution of PLM reflects a gradual expansion in scope and responsibility. Early PLM implementations originated from Product Data Management systems focused primarily on managing CAD files and engineering documentation. As organizational needs expanded, PLM capabilities grew to include engineering change management, bill of materials governance, and alignment between engineering and manufacturing data. In contemporary enterprise environments, PLM increasingly functions as an enterprise-wide digital backbone that integrates with downstream systems such as manufacturing execution, enterprise resource planning, and analytics platforms. These foundational principles of PLM provide the context for understanding the shift toward platform-based PLM architectures, which emphasize scalability, extensibility, and lifecycle-wide data continuity.

### **3. Platform-Based PLM and Its Key Characteristics**

The increasing demand for agility, integration, and scalability has driven a shift from traditional, system-centric PLM implementations toward platform-based PLM architectures. Conventional PLM systems were often deployed as standalone enterprise applications, tightly coupled to specific authoring tools and constrained by rigid data models and workflows. While effective for basic data control, these systems frequently struggled to support cross-domain collaboration, rapid process adaptation, and seamless integration with other enterprise systems. Platform-based PLM addresses these limitations by positioning PLM as a foundational digital layer that supports multiple lifecycle domains within a unified environment.

A defining characteristic of platform-based PLM is the use of a shared and consistent data model that serves as a single source of truth across the product lifecycle. Rather than maintaining separate representations of product information for engineering, manufacturing, and downstream activities, the platform enables multiple lifecycle views to coexist on the same underlying data. This approach improves traceability, reduces duplication, and ensures that changes made in one domain are immediately visible and actionable across others. Role-based access further enhances collaboration by allowing users to interact with relevant PLM capabilities through domain-specific applications while preserving data integrity and governance.

Another key aspect of platform-based PLM is its emphasis on extensibility and integration. Modern PLM platforms are designed to evolve alongside organizational needs, supporting

configuration, customization, and integration without disrupting core functionality. Open interfaces and service-based architectures enable PLM to connect with enterprise resource planning systems, manufacturing execution systems, simulation tools, and analytics platforms. As a result, PLM becomes not only a system for managing product data, but a central digital backbone that supports end-to-end product realization and enterprise digital transformation.

#### **4. Implementation of Product Lifecycle Management Using the 3DEXPERIENCE Platform**

The implementation of Product Lifecycle Management within a platform-based architecture requires more than deploying a software system; it involves establishing a unified digital environment that supports product data continuity, lifecycle governance, and cross-functional collaboration. The 3DEXPERIENCE platform implements PLM by providing a common data backbone where product definitions, lifecycle states, and enterprise processes coexist within a single environment. This approach differs fundamentally from traditional PLM deployments, which often relied on separate systems or tightly coupled integrations to manage different lifecycle stages, leading to data duplication and synchronization challenges.

From an architectural standpoint, PLM implementation within the 3DEXPERIENCE platform is centered on maintaining a consistent and authoritative representation of product information while supporting multiple lifecycle perspectives. Product structures are defined in a way that allows engineering, manufacturing, and downstream views to be logically connected rather than independently managed. Lifecycle states and governance mechanisms regulate how product data progresses from early development to release and beyond, ensuring that changes are controlled, traceable, and visible across all affected domains. This unified implementation model enables organizations to manage product evolution systematically while reducing information fragmentation across departments.

A key aspect of PLM implementation on the 3DEXPERIENCE platform is its emphasis on collaboration and role-based interaction. Instead of exposing users to monolithic PLM applications, the platform provides role-specific access to PLM capabilities aligned with functional responsibilities. Engineers, manufacturing planners, and quality stakeholders interact with the same underlying product data through domain-relevant applications, enabling coordinated decision-making without compromising data integrity. This role-driven approach improves usability and adoption while preserving enterprise-level governance and security.

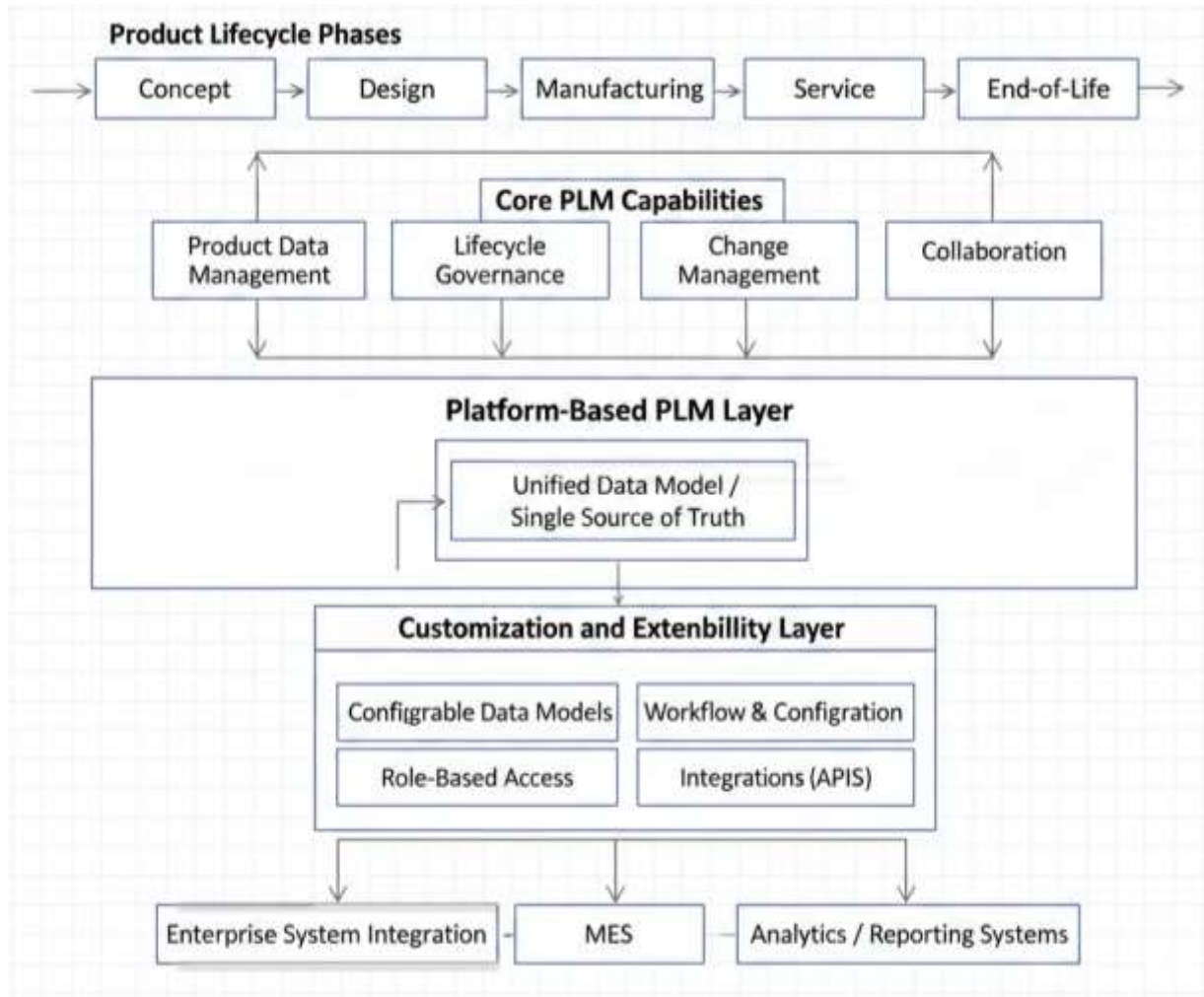


Figure 1 presents a conceptual view of platform-based PLM, highlighting lifecycle coverage, core capabilities, unified data management, and enterprise system integration.

Equally important is the platform's support for scalable and phased PLM adoption. Organizations can implement foundational PLM capabilities such as product data management, lifecycle control, and change governance as an initial step, and progressively extend PLM to additional domains as organizational maturity increases. This incremental implementation model allows enterprises to align PLM deployment with business priorities while maintaining continuity of data and processes. As a result, PLM implementation within the 3DEXPERIENCE platform evolves from a functional system into an enterprise-wide capability that supports integrated product realization and long-term digital transformation objectives.

## **5. Customization and Extensibility of Product Lifecycle Management in the 3DEXPERIENCE Platform**

A critical limitation of many traditional PLM implementations is their inability to adapt effectively to the unique processes, organizational structures, and industry-specific requirements of different enterprises. While standard PLM functionalities provide a foundation for managing product data and lifecycle states, organizations often require tailored behaviors to reflect internal governance models, compliance needs, and operational practices. Platform-based PLM addresses this challenge by enabling controlled customization and extensibility, allowing PLM systems to evolve alongside business needs without compromising data consistency or system stability. In this context, customization is not an optional enhancement but a fundamental capability that determines the long-term success of a PLM implementation.

The 3DEXPERIENCE platform supports customization across multiple layers of the PLM architecture, enabling organizations to align the system closely with their product development and realization processes. At the data level, the platform allows extensions to the underlying data model, making it possible to capture organization- or industry-specific attributes and relationships while preserving a unified product definition. At the process level, lifecycle states, approval workflows, and governance rules can be configured to reflect internal decision-making structures and compliance requirements. Role-based configurations further ensure that users interact with PLM through views and functions aligned with their responsibilities, improving usability and adoption while maintaining enterprise-wide control and traceability.

Beyond configuration, extensibility enables PLM to function as a central component of a broader digital enterprise ecosystem. The 3DEXPERIENCE platform provides mechanisms for extending PLM capabilities through integrations, services, and application-level extensions that connect PLM with downstream systems such as manufacturing execution systems, enterprise resource planning platforms, and analytics environments. These integration capabilities allow product data and lifecycle context to flow seamlessly across enterprise systems, supporting end-to-end product realization and operational visibility. Importantly, extensibility is designed to coexist with standard platform functionality, reducing dependency on custom code and minimizing upgrade and maintenance risks.

Together, customization and extensibility position platform-based PLM as a dynamic and scalable enterprise capability rather than a static system. By embedding organizational logic within configurable frameworks and enabling controlled interaction with external systems, the 3DEXPERIENCE platform allows PLM implementations to remain adaptable in the face of changing business strategies, regulatory demands, and technological advancements. This flexibility is essential for organizations seeking to leverage PLM not only as a data management

tool, but as a digital backbone that supports continuous improvement and long-term digital transformation.

## 6. Discussion

The analysis presented in this paper highlights a clear shift in the role of Product Lifecycle Management from a tool-centric data management system to a platform-based enterprise capability. Traditional PLM implementations were largely effective in controlling design data and enforcing basic governance, but they often struggled to support cross-domain collaboration, scalability, and process adaptability. The emergence of platform-based PLM architectures addresses these limitations by positioning PLM as a central digital backbone that connects product data, lifecycle processes, and enterprise systems within a unified environment.

The implementation of PLM using a platform-based approach, as examined through the 3DEXPERIENCE platform, demonstrates how a shared data model and role-based interaction can significantly improve lifecycle continuity and collaboration. By enabling multiple lifecycle perspectives to coexist on the same underlying product definition, platform-based PLM reduces data fragmentation and enhances traceability across engineering, manufacturing, and downstream activities. This capability is particularly relevant in complex product development environments where frequent changes, regulatory requirements, and global collaboration demand high levels of data consistency and process transparency.

Customization and extensibility emerge as critical enablers of sustainable PLM adoption. The ability to configure data models, workflows, and access mechanisms allows organizations to align PLM behavior with internal governance structures and industry-specific requirements. At the same time, controlled extensibility ensures that PLM can integrate with other enterprise systems without becoming overly dependent on rigid customizations. This balance between standardization and flexibility is essential for maintaining system integrity while supporting continuous organizational and technological evolution.

Despite these advantages, the adoption of platform-based PLM also presents challenges that organizations must address. Effective governance, disciplined data modeling, and change management are required to prevent excessive customization and ensure long-term maintainability. Additionally, organizational readiness and cultural alignment play a significant role in realizing the full benefits of PLM platforms. Technology alone cannot deliver value without corresponding process alignment and stakeholder engagement.



## 7. Research Scope and Contribution

This paper presents a conceptual and architectural study of Product Lifecycle Management with a focus on platform-based PLM implementations. The scope of this research is intentionally defined to analyze PLM from a lifecycle-wide and enterprise perspective, emphasizing foundational concepts, implementation principles, and customization capabilities within a platform-oriented architecture. The study does not aim to provide software usage guidelines, detailed configuration steps, or industry-specific operational case studies. Instead, it concentrates on identifying architectural patterns and strategic considerations that are applicable across multiple industries and organizational contexts.

The primary contribution of this work lies in structuring PLM understanding across three interconnected dimensions: PLM fundamentals, platform-based implementation, and controlled customization and extensibility. By linking these dimensions, the paper highlights how modern PLM platforms address the limitations of traditional, tool-centric systems and support enterprise-wide data continuity, collaboration, and governance. This integrated perspective contributes to existing PLM literature by clarifying the evolving role of PLM as a digital backbone rather than a standalone engineering system.

In addition, the paper contributes a comparative analytical view that distinguishes traditional PLM approaches from platform-based PLM architectures. This comparison helps clarify the strategic implications of adopting platform-oriented PLM solutions, particularly in the context of digital transformation initiatives. The insights presented are intended to support both academic researchers examining PLM evolution and practitioners evaluating long-term PLM implementation strategies.

**Table 1. Comparison Between Traditional PLM and Platform-Based PLM Architectures**

Aspect	Traditional PLM Systems	Platform-Based PLM
Architectural Model	Application-centric	Platform-centric
Data Representation	Fragmented, tool-specific	Unified, shared data model
Lifecycle Coverage	Primarily engineering-focused	End-to-end lifecycle
Collaboration	Department-based	Enterprise-wide, cross-domain
Customization Approach	Limited, code-dependent	Configuration-driven and extensible
Scalability	Rigid, upgrade-sensitive	Scalable and modular

Integration Strategy	Point-to-point integrations	Service-oriented and API-based
Governance	Tool-level control	Platform-level lifecycle governance
Digital Transformation Role	Supporting system	Enterprise digital backbone

This table provides a conceptual comparison intended to highlight architectural and strategic differences rather than software-specific features.

## 8. Conclusion and Future Work

This paper presented a structured analysis of Product Lifecycle Management with a focus on its evolution toward platform-based architectures. By examining PLM fundamentals, platform-oriented implementation principles, and the role of customization and extensibility, the study highlighted how modern PLM solutions address limitations inherent in traditional, tool-centric systems. The analysis demonstrates that PLM has evolved beyond its original role as a design data management system to become an enterprise-wide digital backbone supporting lifecycle continuity, governance, and collaboration.

The discussion of PLM implementation using a platform-based approach illustrates the importance of a unified data model, lifecycle governance, and role-based interaction in managing complex products and distributed development environments. The findings emphasize that effective PLM implementation is not solely dependent on technology deployment, but also on architectural alignment with organizational processes and long-term scalability requirements. In this context, controlled customization and extensibility emerge as critical enablers that allow organizations to adapt PLM behavior to their specific operational needs while maintaining data integrity and upgrade sustainability.

Future research may extend this work by incorporating empirical studies that evaluate the organizational and operational impact of platform-based PLM adoption across different industries. Quantitative assessments of PLM maturity, implementation outcomes, and lifecycle performance metrics could provide further validation of the concepts discussed. Additionally, the integration of emerging technologies such as artificial intelligence, digital twins, and model-based systems engineering within PLM platforms presents significant opportunities for advancing PLM research and practice. As digital transformation initiatives continue to evolve, further exploration of PLM as a central enabler of enterprise-wide digital ecosystems remains a promising direction for future investigation.

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