International Journal of Research in Advanced Engineering and Technology
www.allengineeringjournal.in
ISSN: 2455-0876
Received: 27-10-2024, Accepted: 30-11-2024, Published: 15-12-2024
Volume 10, Issue 2, 2024, Page No. 62-66

A review of product data management frameworks: TOE adoption model, PLM integration, and cloud-based implementation

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Abstract
Product Data Management (PDM) has emerged as a critical technology for improving product information management, collaboration, and operational efficiency in modern manufacturing organizations. This review paper examines various PDM implementation frameworks with a particular emphasis on the Technology-Organization-Environment (TOE) adoption model, Product Lifecycle Management (PLM)-based business operations, and cloud-based PDM frameworks. The review synthesizes findings from previous literature and case studies to identify the technological, organizational, and environmental factors that influence successful PDM adoption. It discusses the role of PDM in supporting product development activities through workflow automation, version control, system integration, and collaboration across engineering and manufacturing functions. Furthermore, the paper explores the integration of PDM with enterprise systems such as ERP, MES, CRM, and SCM to facilitate digital transformation and improve organizational performance. The proposed cloud PDM framework addresses implementation strategies, feasibility analysis, deployment models, and key technical challenges including data security, system integration, and customization. Overall, the review demonstrates that an effective PDM framework enhances product data accessibility, decision-making, operational efficiency, and competitiveness while providing a strong foundation for sustainable digital manufacturing practices. The findings provide valuable guidance for researchers and industrial practitioners seeking to implement robust and scalable PDM solutions.

Keywords: PDM, Technology-Organization-Environment, Product Lifecycle Management, operational efficiency, data accessibility

Introduction

One of the biggest obstacles in implementing PDM systems in companies is the lack of a thorough basis. By providing a rational and pragmatic approach to PDM implementation, this chapter helps organisations design, install, and manage PDM systems. The recommended frameworks help manufacturing firms get the strategic and operational benefits of Product Data Management [1].

T-O-E Adoption Model for PDM

A theoretical model for the adoption of Product Data Management (PDM) systems may be derived from the findings of the survey in addition to the comprehensive analyses of the case studies. Since having a solid knowledge of the requirements of the company is essential to the implementation of PDM, the proposed approach begins with the requirements of the organization. Companies use product data management (PDM) systems in order to make use of the anticipated benefits, capabilities of the system, and to enhance product information management (PIM) [2].

In order to conduct an all-encompassing analysis of the adoption of industrial technology, the proposed method use the Technology-Organization-Environment (T-O-E) paradigm instead. A number of technological, organisational, and environmental aspects that have an effect on the adoption of PDM systems have been taken into consideration by the framework. Incorporating these three aspects throughout the PDM implementation process has the potential to result in increased success and sustainability [3].

Validation of the model's constructs was accomplished via the utilisation of survey and case study data. Interoperability, information security, capability, & stakeholder collaboration are all examples of technological aspects. System integration is another. Size, structure, strategic goals, resources, managerial support, and operations are all characteristics that make up elements of an organization. It is possible for decisions made by organisations or the adoption of new technologies to be influenced by environmental factors such as government regulations and standards, competition in the market, economic conditions, and unanticipated events.

Results suggest that controlling these three factors may boost an organization's success. The operational performance metrics include productivity, profitability, market share, and workplace efficiency. Though PDM's impact to these performance indicators has not been fully explored, the survey and case studies suggest that it improves organisational performance over time. PDM systems may help manufacturing companies become more efficient and competitive by improving data accessibility, collaboration, business processes, and decision-making [4].

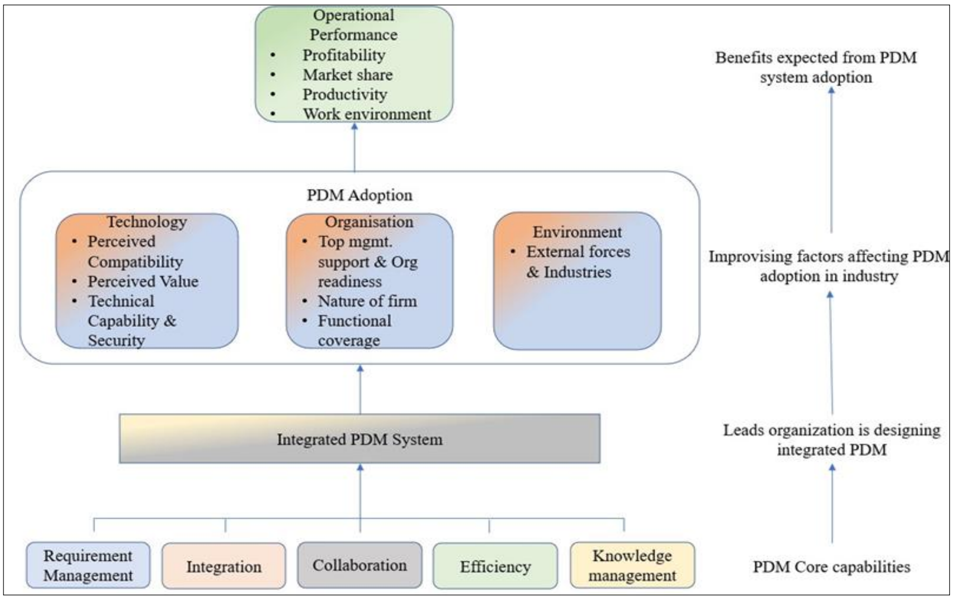

Fig 1: A framework for the implementation of TOE-based PDM

Structure of PDM system. PDMS' primary functions form the foundation. Due to these attributes, the company implements integrated PDM. An organisation may use several integration points and ES for integrated PDM systems. An IT project is needed to incorporate PDM [5].

T-O-E impacts PDM adoption. Similar survey and case study findings suggest the framework above may explain PFM adoption in a company. Implementing PDM correctly may also improve operational performance [6].

Framework for Business Operations that are built on PDM Framework

A strategy to defining business processes, including several phases of NPD, by using the capabilities of PLM systems was shown in the case study. The PLM system has planned out a number of operations, beginning with requirements management and ending with mass manufacturing. For this reason, we have investigated workflow, version control, inbuilt CAD platform integration, and bespoke features and connectors. Researchers have examined the NPD process and plotted it against the various literature review categories [7].

1. Proposed theoretical paradigm for PD that integrates PDM

The following structure has been suggested for linking PLM studies with PD initiatives. Every stage builds on the one before it and every stage after it in some way. The proper research has, however, been linked to the descriptions of each stage.

We manage client requests via RFQ. This includes working with many subject field experts to assess the requests' viability. The system includes access control and traceability. System output informs product design [8].

Work together to refine demands into design requirements and be transparent about how requirements become product features. Needs become design requirements via collaboration. Since numerous designers are working on different components and presenting the outcomes concurrently, this method is collaborative. As we work to make PDM a comprehensive system, we created an automated platform to decrease drafting time and effort [9].

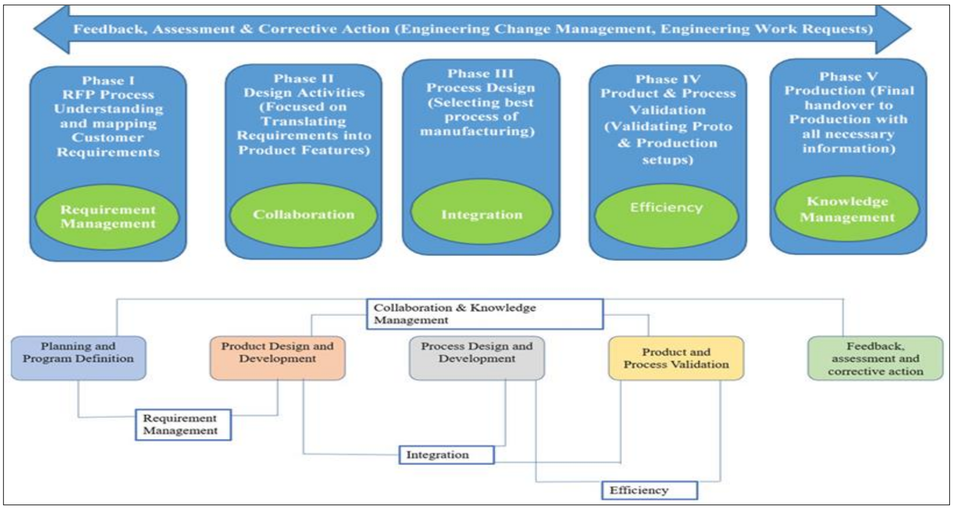

Fig 2: Conceptualisation of PLM-Based PD Initiatives

2. Engineering Design for Product Lifecycle Management (PLM) Based PD

A general method is provided for practitioners by developing an architectural framework for PLM-based PD, which is based on the theoretical foundation. It lays out the steps a company can take to get the most out of PLM. The input provided by the professional group has been beneficial.

Recognising the PLM system as a foundation upon which to build connections to other applications is equally crucial. Connectivity with apps that handle requirement gathering, product design, and manufacturing execution is also possible, as is shown via the case study method. The architectural structure that connects different applications in an organization is shown in Figure [10].

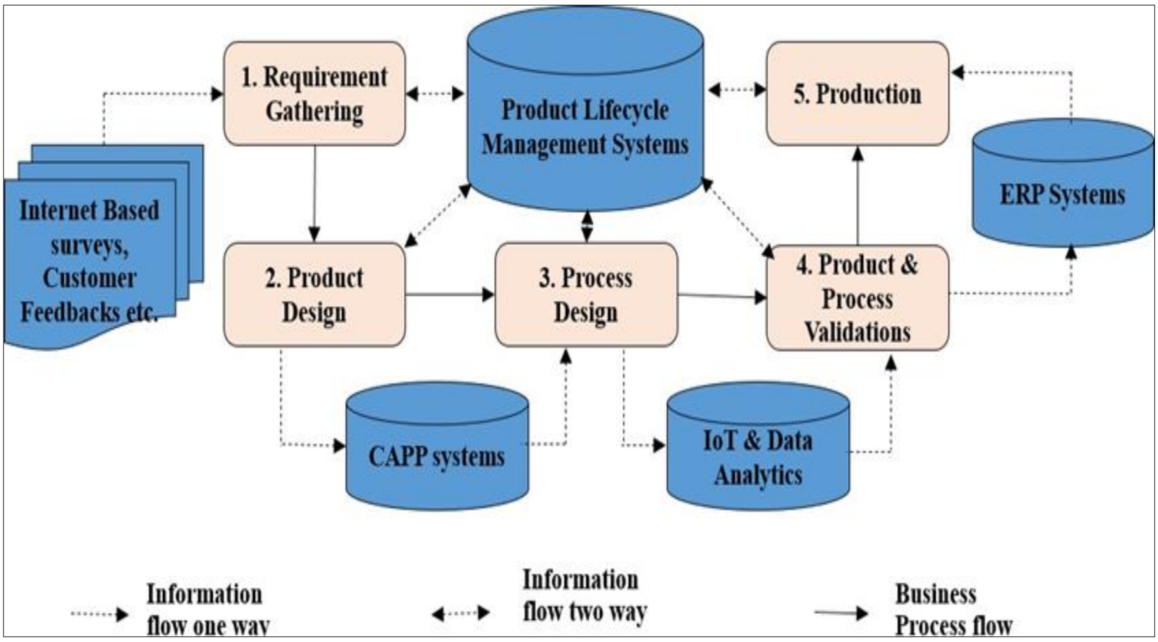

Fig 3: A Structure for Product Lifecycle Management (PLM)-Based PD Operations

Within the framework, the several components that might be used to include PD activities are shown. According to its name, the phased design process is exactly what it sounds like: a paradigm or concepts. On the other hand, in order to turn this concept into a reality, a variety of different methods will be required. An excellent illustration of this is the need to make use of computer-aided process planning in order to come up with information about the process and to extract information regarding the design [11].

There is a possibility that a digital footprint of PD activities may be established if PLM systems were connected with other systems, such as web applications, CAPP, data analytics, and ERP. Enterprise resource planning (ERP) systems and the process of integrating them have been the subject of research and writing. To increase organization efficiency and aid digital transition, future research might study various business system components. After integrating Product Lifecycle Management (PLM) beyond the present application, businesses might gain visibility, collaboration, and decision-making capability [12].

Modern engineering and modelling software may produce and modify product data for design, simulation, and analysis. These systems can interact with PLM systems via proprietary interfaces and conventional data exchange methods. Conventional integration procedures successfully integrate ERP to PLM. PLM would then be linked with management information systems (MES), customer relationship management (CRM), supply chain management (SCM), as well as quality management systems in order to realise a more connected digital organization.

Because of their workflow capabilities, PLM systems may automate many organisational procedures. Sequential workflows optimise engineering modifications, approval flow, new the creation of goods, and other company tasks while reducing human procedures and guaranteeing consistency. PLM systems store product information, whereas workflow control coordinates project activity across functional divisions.

Framework for Cloud PDM

The literature study helped identify several problems, and the suggested cloud PDM solution fixes those problems. The method has also been made more generic so that other organisations may adopt it. The suggested method is much more convincing since it has confirmation from several sources.

1. Proposed Framework

Assuming that the prerequisites pertaining to management difficulties are in good alignment, the current research offers a framework that would help organisations create the cloud PDM strategy. The many obstacles and requirements that must be met before an organization may implement a cloud PDM system are shown in Figure.

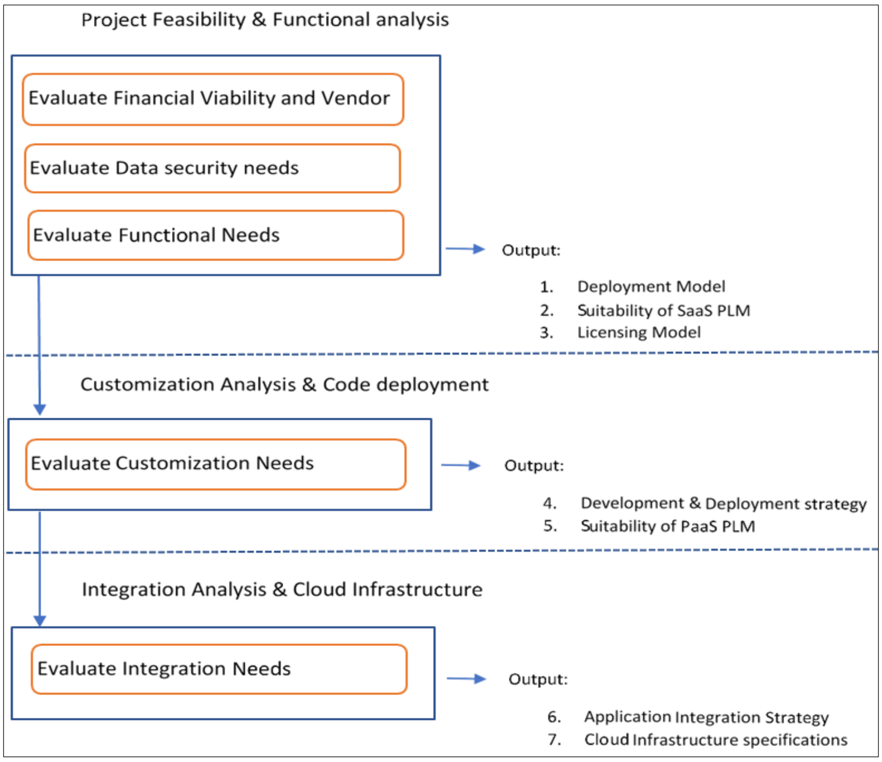

Fig 4: The cloud PDM framework

1.1 The project's functional analysis and feasibility study

The first step in the process involves the distribution of resources and the use of the aid of suppliers. For this attempt to be successful, it is necessary to have both finance and upper-level management. During the period of feasibility, it is crucial to discuss a number of important themes, including the need of the system, financial sustainability, and concerns over security. Before submitting the Request for Proposal (RFP) to potential suppliers, it is customary to at this stage complete the system expectations that have been established [13].

The selection of a deployment strategy for the cloud is determined by the security concerns of a business, while the selection of a service model for product lifecycle management (PLM) is determined by the needs of functional features, customisation, and integration. Companies may choose to use best practices in requirement management and traceability, which are already in place, in order to provide a seamless transition to cloud-based PDM.

2. Technical Challenges

- **Data security**

The deployment approach is crucial to cloud-based Product Data Management (PDM) system success. Functional deployment provides the finest security, data management, and policy compliance for private clouds. Internal users utilise the program most in this deployment. Confidential cloud environments benefit sensitive data-handling commercial applications [14].

Data safety and privacy standards allow business partners, suppliers, or vendors to access product information. To secure critical product assets and intellectual property, organisations must employ strict security protocols. Manufacturing firms utilise risk assessments, penetration testing, verification methods, encryption, and continuous security monitoring to avoid unauthorised access or data breaches. Using cloud-based PDM systems allows safe data storage, regulated data exchange, and operational and regulatory security.

- **Integration**

Functional deployment, where employees utilise the app, provides the best security, data management, and policy compliance for a private cloud. Private cloud infrastructures for sensitive data-handling business applications.

Suppliers, vendors, & business partners may access product information under data safety and privacy laws. Organisations must employ strict security protocols to secure critical product information and intellectual property. Manufacturing companies utilise vulnerability assessments, penetration tests, authentication procedures, encryption, and continuous security monitoring to prevent data theft and unauthorised access. Cloud-based PDM systems provide safe data storage, managed information transfer, and organisational and legislative security.

- **Customization**

The main driver of cloud PDM system modification is functional needs. If a vendor's SaaS platform doesn't meet business process needs, companies frequently customise. Most on-premises PLM systems may be modified. Using appropriate service models may help [15].

Conclusion

Product Data Management has become an essential component of digital manufacturing by enabling organizations to manage product information efficiently throughout the product lifecycle. This review highlights that successful PDM implementation depends not only on technological capabilities but also on organizational readiness and environmental factors, as explained through the Technology-Organization-Environment (TOE) framework. The study further demonstrates that integrating PDM with Product Lifecycle Management systems and enterprise applications enhances collaboration, workflow automation, data consistency, and decision-making across product development processes. The proposed cloud-based PDM framework offers organizations a practical roadmap for adopting scalable and flexible solutions while addressing critical challenges related to security, integration, deployment, and customization. Collectively, the reviewed frameworks indicate that PDM significantly contributes to improved operational performance, productivity, and digital transformation in manufacturing industries. Future research should focus on validating these frameworks across different industrial sectors, investigating the application of emerging technologies such as artificial intelligence, digital twins, and Industry 4.0, and developing standardized implementation models that can support sustainable and intelligent manufacturing environments.

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