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Design and Validation of a Cognitive 360° PLM Framework for Autonomous and Adaptive Product Lifecycle Decisions

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Research Scholar

Abstract: PLM is holistic and cross functional business activity addressing not only product but also organizational structure, working methods, processes, people, information structure and Information system. PLM manages each individual products across its lifecycle this helps companies to have full control over their product and serve the market effectively. The research aims to examine how integrated lifecycle information and adaptive decision-making can support more efficient product management, identify improvement opportunities, and generate measurable business value. A proposed empirical evaluation using relevant industrial case studies, performance data, and comparative analysis could assess the framework's effectiveness against established PLM practices. The expected contribution is a structured approach to connecting PLM integration, data-driven intelligence, continuous adaptation, and value realisation within a single lifecycle management framework. The study seeks to provide both theoretical insights and practical guidance for organisations pursuing operational excellence, sustainable product development, and improved long-term business performance.

Keywords: Product-system; Lifecycle Management; Industry 4.0; Digital Twin, PLM, Business Process Improvement, System Integration, 360° PLM, Adaptive PLM, Data-Driven Decision Support, Lifecycle Optimisation, Return on Investment, Sustainability, Intelligent Analytics.

INTRODUCTION

Product Lifecycle Management (PLM) is need of the industries it acts a tool to manage product-related data, people, processes, and technologies in an integrated manner throughout the product lifecycle. It helps organisations improve product quality, reduce costs, accelerate product development, support better decisions, maintain regulatory compliance, and achieve sustainable business performance. Although several research gaps in Product Lifecycle Management (PLM) have been identified across various industrial sectors, these gaps highlight the need for further investigation into emerging challenges, integration mechanisms, and innovative approaches to lifecycle optimisation. Accordingly, the authors conclude by identifying promising avenues for future research, including adaptive PLM frameworks, intelligent data-driven decision support, integration of enterprise systems, AI-enabled lifecycle optimisation, real-time performance monitoring, regulatory compliance, sustainability, and the measurement of financial and operational returns. These research directions offer opportunities to enhance PLM effectiveness, improve organisational performance, and support sustainable product lifecycle management.

Today, many industries, including automotive and transportation, aerospace and defence, electronics and semiconductors, medical devices and healthcare products, industrial machinery, and consumer goods, use Product Lifecycle Management (PLM) to manage product-related data, processes, and activities throughout the product lifecycle.

Definition

Product Lifecycle Management (PLM) is a systematic approach to managing all information, processes, people, and technologies associated with a product throughout its entire lifecycle, from initial concept and design to manufacturing, distribution, service, and end-of-life disposal or recycling.

PLM integrates different business functions, such as product design, engineering, manufacturing, marketing, sales, and customer service, to improve collaboration, product quality, operational efficiency, innovation, and overall business performance.

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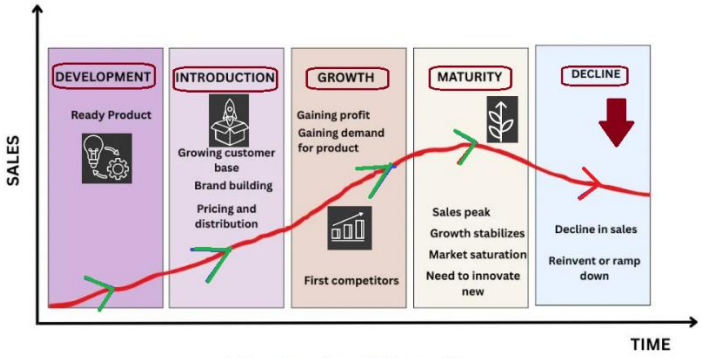
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UNDERSTANDING PRODUCT LIFECYCLE

The product lifecycle refers to the sequence of stages a product passes through from the initial idea and development to market introduction, growth, maturity, decline, and eventual retirement or recycling.



The Product Lifecycle

In PLM, the lifecycle is managed as an integrated process that connects product data, people, technologies, and business activities throughout the product's existence.

- **Development**: The initial phase is the development of product which indicates that the product to get launched in the market.
- **Introduction**: In the introduction phase the customer base will start to grow, we need to create a brand identity while pricing and distribution also plays a key role.
- **Growth**: In the growth phase the sales or product will boom creating profits, more customers will start demanding for product. There may be only few competitors exists in the market.
- **Maturity**: At the maturity phase the product will have a huge peak in the sales, there would be high revenue generation. Growth will get stabilized and there would be alert for saturation in the market which will alarm us with the need to innovate a new product.
- **Decline**: At the Decline phase the sales of the product will decline slowly and will reach out to a situation where we need to ramp down the existing product and reinvent new product based on emerging customer requirements

How PL is different from PLM

- Product lifecycle (PL): The stages a product passes through from its initial concept to retirement.
- Product Lifecycle Management (PLM): The management approach, processes, data, and technologies used to coordinate and optimise those stages.

A Product-Centric Approach to Product Lifecycle Management (PLM) places the product at the centre of organisational processes, data, technologies, decisions, and business activities throughout its lifecycle. Instead of managing design, manufacturing, supply chain, quality, service, and sustainability as isolated functions, the approach connects them through a common, continuously updated product information model.

PLM Strategy for Enhancing Product Life Cycle and Sustainability

The Product Lifecycle Management (PLM) strategies should be aligned with the five stages of the product life cycle: Development, Introduction, Growth, Maturity, and Decline. At each stage, PLM integrates product data, design decisions, quality, cost, market feedback, maintenance, and sustainability to maximise product value and support long-term company growth.



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Product life-cycle stage	Key PLM strategies	Sustainability contribution
Development	Requirements management, digital prototyping, design for reliability, modular design, lifecycle cost and environmental assessment	Prevents wasteful design choices and reduces future repair and replacement costs
Introduction	Product configuration control, quality monitoring, warranty analysis, customer feedback integration, defect correction	Improves reliability and reduces early product failures
Growth	Manufacturing optimisation, supplier integration, standardisation, capacity planning, product performance analytics	Reduces resource consumption, production waste, and unit cost
Maturity	Predictive maintenance, component upgrades, product redesign, refurbishment, service optimisation	Extends useful life and maintains product competitiveness
Decline	End-of-life planning, spare-parts strategy, product recovery, remanufacturing, recycling, controlled discontinuation	Recovers material and economic value and reduces waste

Need of PLM System

Companies need PLM to develop a excellent product so they need PLM during ideation, innovation and all the way across product lifecycle. PLM supports product innovation, research & development, prototyping, testing, servicing and retirement. Thus, it makes possible for companies to develop, sell and serve excellent product to their customer with minimum cost, better quality and with limited time frame.

Product Lifecycle Management (PLM) is needed to manage the increasing complexity of products, coordinate business activities, improve collaboration, and maintain consistent product information throughout the product lifecycle. It helps organisations integrate design, engineering, manufacturing, marketing, sales, and customer service into a unified management system

PLM Matrices -Need Analysis

It helps an organisation identify its current product lifecycle challenges, measure performance gaps, determine business requirements, and prioritise PLM capabilities that deliver measurable value.

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No.	Performance area	Metric	Measurement
1	Cost	Product lifecycle cost	Total cost across defined lifecycle stages
2	Financial	Return on Investment (ROI)	Net benefits ÷ total investment cost × 100
3	Development	Time-to-market	Time from approved concept to market launch
4	Engineering	Change cycle time	Average time to process engineering changes
5	Quality	Defect rate	Defective units ÷ total units × 100
6	Manufacturing	First-pass yield	Units passing without rework ÷ total units × 100
7	Data management	Data accuracy	Correct records ÷ records audited × 100
8	Integration	Integration success rate	Successful transactions ÷ total transactions × 100
9	Collaboration	Approval time	Average time required for workflow approvals
10	Compliance	Traceability coverage	Requirements with complete evidence ÷ applicable requirements × 100
11	Sustainability	Material waste rate	Material waste ÷ total material input × 100
12	Adaptation	Adaptation response time	Time from detecting a change trigger to an approved response
13	Customer	Customer satisfaction	Survey score or defined satisfaction index
14	Innovation	Product reuse rate	Reused approved components ÷ eligible components × 100

PLM Capabilities

1. Product Data Management
Centralises product documents, CAD files, specifications, bills of materials (BOMs), and product records.

2. Product Design and Engineering
Supports product modelling, simulation, prototyping, design validation, and engineering collaboration.

3. Version and Change Management
Controls product revisions, engineering change requests, approvals, and traceability.

4. Workflow and Process Management
Automates reviews, approvals, task assignments, release processes, and cross-functional coordination.

5. Enterprise System Integration
Connects PLM with ERP, CRM, MES, supply chain systems, and manufacturing applications.

6. Quality, Compliance and Governance
Supports quality planning, audit trails, regulatory compliance, access controls, and product traceability.

7. Analytics and Intelligent Decision Support
Uses product data, business intelligence, predictive analytics, and AI to improve decisions and identify risks.

8. Sustainability and Lifecycle Management
Helps evaluate lifecycle costs, material usage, environmental impact, repairability, reuse, and recycling.



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Major stakeholders

1. Product Design and Engineering Team
2. Manufacturing and Operations Team
3. Marketing and Sales Team
4. Customers and End Users
5. Sustainability team
6. Suppliers and Supply Chain Partners
7. Regulatory and compliance teams

INDUSTRY READINESS FOR PLM

PLM readiness measures whether an organisation is prepared to implement and benefit from PLM; It indicates the degree to which an organisation is prepared to implement, integrate, operate, and continuously improve Product Lifecycle Management (PLM). It evaluates whether the organisation has the necessary strategy, people, processes, data, technology, governance, and financial resources to achieve its PLM objectives.

Major dimensions of PLM readiness

1. Strategic readiness

Clear PLM objectives, management commitment, business alignment, and a defined implementation roadmap.

2. Data readiness

Data accuracy, completeness, standardisation, ownership, accessibility, and product information quality.

3. Process readiness

Standardised product development, change management, approval workflows, quality procedures, and lifecycle responsibilities.

4. Technology readiness

Availability of PLM software, infrastructure, CAD/CAE, ERP, MES, APIs, and integration capabilities.

5. People and organisational readiness

Employee skills, training, cross-functional collaboration, user acceptance, and readiness for organisational change.

6. Governance and security readiness

Data ownership, access controls, version management, audit trails, intellectual property protection, and regulatory responsibilities.

7. Financial and performance readiness

Budget availability, total cost of ownership estimates, expected ROI, baseline KPIs, and benefits-realisation plans.

8. Adaptation and innovation readiness

Ability to use lifecycle feedback, analytics, AI where appropriate, performance monitoring, and controlled process adaptation.

The PLM Adaptation – Early Adaptation benefits

PLM enable us to focused on manufacturing, company, Functions, Activities, Timeline, Customer, Portfolio, Product Life, Process, roles and responsibilities, Profit and globalization. It is a product centric approach

GAP Analysis

Gap analysis in Product Lifecycle Management (PLM) is the systematic comparison of an organisation's existing product management practices before PLM implementation with its desired or achieved capabilities after PLM implementation. It identifies weaknesses in data management, collaboration, workflows, product quality, cost, and decision-making, helping organisations evaluate the improvements introduced by PLM.

Before PLM Implementation

- Product data stored in separate files, spreadsheets, and departmental systems.
- Multiple versions of drawings and specifications.
- Manual communication through emails and meetings.
- Slow engineering change approvals.
- Repeated work, errors, and design duplication.

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- Limited visibility into product lifecycle costs.
- Customer feedback not consistently linked to product design.

After PLM Implementation

- Centralised and controlled product information.
- Version control and a consistent product data source.
- Connected teams and collaborative workflows.
- Structured engineering change and approval processes.
- Improved reuse, traceability, and quality control.
- Better lifecycle cost and performance visibility.
- Customer and service feedback incorporated into product improvement.

Quantitative gap analysis

The following figures are hypothetical and demonstrate how a company can measure the difference between its baseline and post-implementation performances

KPI	Before PLM	After PLM	Improvement
Product development cycle	12 months	9 months	25% reduction
Engineering change cycle	10 days	4 days	60% reduction
Design rework rate	15%	8%	7 percentage-point reduction
Product data retrieval	30 minutes	5 minutes	83.3% reduction
On-time engineering releases	70%	90%	20 percentage-point increase

For a KPI where lower values are better:

$$\text{Improvement (\%)} = \frac{\text{Before} - \text{After}}{\text{Before}} \times 100$$

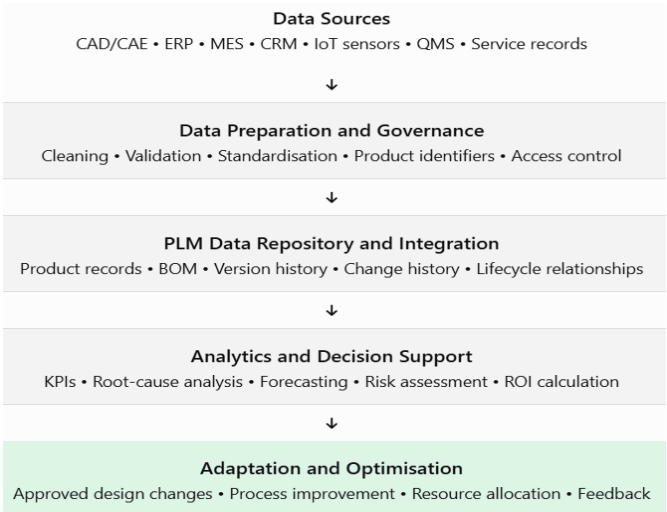
For a KPI where higher values are better:

$$\text{Improvement (percentage points)} = \text{After (\%)} - \text{Before (\%)}$$

The distinction matters: a rise from 70% to 90% is a 20-percentage-point increase, or a 28.6% relative increase.

PLM driving data to Decisions

PLM data points are individual pieces of information collected, generated, measured, or analysed throughout a product's lifecycle.



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They provide the evidence needed to monitor product performance, support management decisions, calculate ROI, identify risks, and enable continuous PLM adaptation.

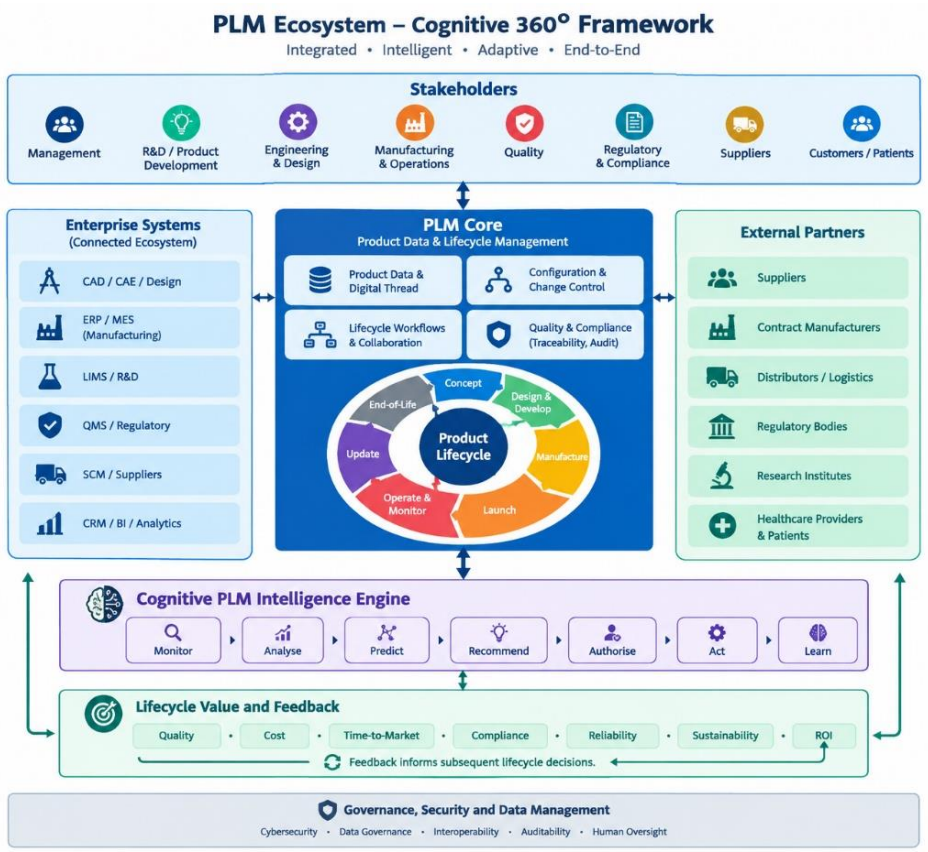
In a 360° PLM strategy, data points connect product design, manufacturing, supply chains, customers, finances, compliance, and sustainability into an integrated decision-support system.

PLM INTEGRATION ARCHITECTURE

PLM Integration Architecture (Product Lifecycle Management Integration Architecture) is a layered structure that connects PLM software with engineering, manufacturing, enterprise, supply-chain, customer-management, and analytics systems. It enables consistent product information exchange from product design to manufacturing, service, and end-of-life.

The PLM integration diagram illustrates how stakeholders, enterprise systems, external partners, and the PLM core work together to manage a product throughout its lifecycle.

1. **Stakeholders:** Define product requirements and make decisions.
2. **Enterprise** Systems: Provide design, manufacturing, quality, laboratory, and supply-chain data.
3. **PLM Core:** Manages product information, configurations, lifecycle workflows, and change control.
4. **External Partners:** Connect suppliers, contract manufacturers, distributors, and regulatory bodies.
5. **Cognitive PLM** Intelligence Engine: Monitors, analyses, predicts, recommends, acts within authorised limits, and learns from outcomes.
6. **Lifecycle Value and Feedback:** Measures quality, cost, time-to-market, compliance, reliability, sustainability, and ROI.
7. **Governance, Security and Data Management:** Ensures data integrity, cybersecurity, traceability, interoperability, and human oversight.



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Major systems integrated with PLM

System	Purpose of integration	Example of information exchanged
CAD / CAE	Connect design and engineering	3D models, drawings, simulations
ERP (Enterprise Resource Planning)	Connect product design with business operations	Approved BOMs, material codes, costs
MES (Manufacturing Execution System)	Connect engineering with shop-floor production	Work instructions, revisions, production feedback
CRM (Customer Relationship Management)	Link customer needs with product development	Requirements, complaints, feature requests
SCM / Supplier systems	Coordinate suppliers and materials	Supplier parts, specifications, lead times
BI / AI systems	Enable analytics and decision support	Quality trends, cost analysis, lifecycle KPIs
IoT / Digital Twin	Connect products in operation with engineering data	Sensor readings, failures, performance data
QMS (Quality Management System)	Manage quality and corrective action	Inspection results, non-conformances, corrective actions
Finance systems	Link product decisions with financial performance	Development costs, budgets, product profitability

LIMITATIONS OF PLM INTEGRATION ARCHITECTURE

PLM (Product Lifecycle Management) integration architecture connects PLM with systems such as CAD, ERP, MES, CRM, SCM, BI and IoT. Although it improves data sharing and coordination, several technical, organisational and financial limitations can affect its performance.

Major limitations

Limitation	Explanation	Impact
High implementation cost	Software licences, integration tools, infrastructure and consultancy can be expensive.	Increased project cost
System compatibility	Different applications may use different data formats, interfaces and standards.	Difficult data exchange
Data inconsistency	Duplicate, incomplete or outdated records may exist across connected systems.	Incorrect decisions
Legacy-system limitations	Older applications may lack modern APIs or integration capabilities.	Complex integration
Integration complexity	Many interconnected systems create dependencies and potential points of failure.	Difficult maintenance
Real-time synchronisation	Network delays, processing queues and system downtime can delay updates.	Outdated information
Cybersecurity risks	Integration expands the number of interfaces through which data could be exposed.	Intellectual property or data loss
Data governance challenges	Departments may disagree about data ownership, definitions and access rights.	Conflicting records



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Organisational resistance	Employees may resist new processes and standardised workflows.	Slow adoption
Vendor dependency	Proprietary formats and interfaces may make migration difficult.	Reduced flexibility
Scalability limitations	Growing product data, users, devices and transactions can strain the architecture.	Performance degradation
AI and analytics limitations	Poor-quality data, model errors and insufficient explainability can reduce insight quality.	Unreliable recommendations
Difficult change management	An engineering change may need coordinated updates across several systems.	Delays and errors
Limited lifecycle visibility	Some systems may not capture complete product information from concept to retirement.	Incomplete lifecycle decisions

2.Technical limitations

- **Data interoperability**

Different systems may represent the same product differently. For example, a component identifier in PLM may not match the material identifier in ERP.

- **Integration failure**

A network interruption or failed interface can prevent approved product changes from reaching downstream systems.

- **Real-time limitations**

Not every integration supports immediate updates. Some processes use scheduled batch transfers, making information temporarily stale.

- **Security and access control**

Information shared with suppliers, cloud platforms or external applications requires consistent authentication, authorisation and auditing.

3. Organisational and strategic limitations

- **Lack of standardisation**: Departments may use different naming conventions, product codes and workflows.
- **Skill gaps**: Employees may lack expertise in PLM administration, integration engineering and data governance.
- **Unclear accountability**: It may be difficult to determine which department is responsible for correcting conflicting information.
- **Uncertain return on investment**: Benefits can be difficult to quantify, particularly when integration costs are high.
- **Cross-department coordination**: Engineering, finance, manufacturing and supply-chain teams may have conflicting priorities.

4. Limitations in adaptive and AI-driven PLM

For research involving adaptive PLM and intelligent decision support, additional challenges arise:

- **Poor feedback quality**: Incorrect field data can lead to inappropriate improvement recommendations.
- **False alerts**: Predictive models may identify problems that do not actually exist.
- **Limited explainability**: Users may not understand why an AI system recommends a product change.
- **Uncontrolled adaptation risk**: Automatically applying a recommendation without engineering, safety or regulatory approval may create serious problems.
- **Model drift**: Predictive performance may decline as products, operating conditions and user behaviour change.

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PLM FOR FINANCIAL PRODUCTS VS. ENGINEERING PRODUCTS

The main difference: Engineering PLM manages the physical or engineered product and its technical configuration, while financial product lifecycle management manages financial offerings, contractual terms, pricing, risk, compliance, and customer outcomes

Dimension	PLM for financial products	PLM for engineering products
Product examples	Loans, insurance, credit cards, deposits, mutual funds	Automobiles, machinery, electronics, industrial equipment
Product nature	Financial service, contract, or investment offering	Physical product or engineered system
Design focus	Features, rates, fees, eligibility, terms and conditions	CAD models, materials, components, specifications
Core data	Customer segments, rates, risk parameters, contracts	CAD files, bills of materials (BOMs), drawings, revisions
Development	Financial modelling, product configuration, legal review	Design, simulation, prototyping, engineering validation
Testing	Financial scenario testing, system testing, compliance checks	Physical testing, simulation, reliability and safety testing
Production or delivery	Digital or branch-based product launch and service delivery	Manufacturing, assembly, distribution and installation
Change management	Repricing, policy changes, revised eligibility or product terms	Engineering change orders, component and design revisions
Risk management	Credit, market, liquidity, fraud, conduct and operational risks, as applicable	Design, safety, quality, manufacturing and supply-chain risks
Regulatory focus	Financial regulations, disclosures, consumer protection	Product safety, technical standards, environmental requirements
End-of-life	Product closure, migration, run-off, contract completion	Retirement, dismantling, reuse, remanufacturing and recycling
Performance measures	Profitability, default rate, retention, complaints, risk-adjusted returns	Quality, cost, reliability, time-to-market, warranty and sustainability

PLM Deployment Team

A PLM team is a cross-functional group of professionals responsible for managing a product's information, processes, decisions, and performance throughout its entire lifecycle — from concept and design to manufacturing, sales, maintenance, and end-of-life management.

For a research-oriented PLM model, the team can be organised around three connected groups:

- **Strategic team**: Product leadership, finance, and senior management.
- **Operational team**: Engineering, manufacturing, quality, procurement, and service.
- **Digital intelligence team**: PLM administrators, data engineers, AI specialists, and analytics professionals.

These groups share product lifecycle data and collaborate on decisions. An adaptive PLM framework adds a feedback mechanism that uses product performance, cost, quality, and sustainability indicators to improve subsequent decisions.

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PLM Team Functioning

1 Plan

Define product requirements, market needs, budget, and lifecycle goals.

2 Design

Develop product models, specifications, and engineering changes.

3 Validate

Test quality, safety, performance, cost, and compliance.

4 Manufacture and deliver

Coordinate production, suppliers, documentation, and release.

5 Monitor and improve

Collect operational and customer feedback and update future designs.

6 Retire and recover

Manage disposal, reuse, recycling, and lessons learned.

PLM Key Drivers

PLM drivers are the internal and external forces that motivate an organisation to adopt, implement, integrate and continuously improve Product Lifecycle Management (PLM).

They explain why an organisation needs PLM, what triggers its adoption, and what encourages better product lifecycle performance.

PLM drivers

Driver category	Key drivers	Expected outcome
Strategic	Innovation, competitiveness, differentiation	Stronger market position
Operational	Productivity, quality, reduced rework	Improved efficiency
Financial	Lifecycle cost, profitability, return on investment	Better financial performance
Technological	AI, digital twins, IoT, data integration	Intelligent decision-making
Organisational	Collaboration, knowledge sharing, standardisation	Better coordination
Customer-oriented	Personalisation, reliability, feedback	Higher customer satisfaction
Environmental	Circular economy, material recovery, carbon reduction	Sustainable products
Regulatory	Traceability, safety, documentation	Improved compliance
Supply chain	Supplier coordination, change management	Greater resilience

PLM & ASSOCIATED SYSTEMS – BUILDING ECOSYSTEMS

A) Batch Manufacturing System and PLM

Batch manufacturing is a production method in which products are manufactured in groups or batches. Product Lifecycle Management (PLM) is a management approach that coordinates product information, processes, and decisions throughout the product's entire lifecycle.

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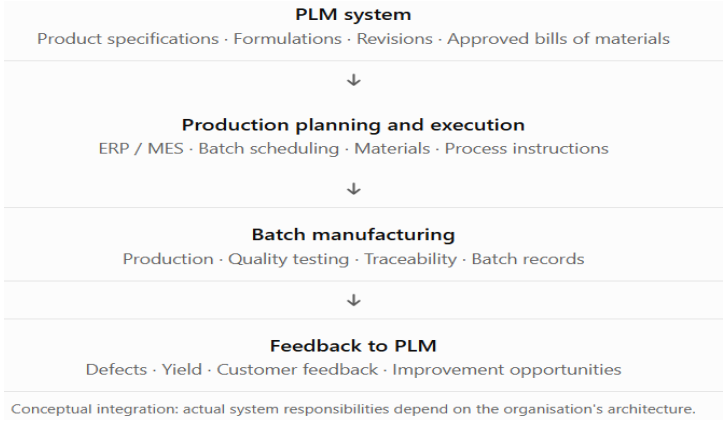
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The key difference is that batch manufacturing focuses on how products are produced, whereas PLM focuses on how products are managed from conception to end of life.

Integrated Approach of PLM & BMS Systems

PLM and batch manufacturing are not competing alternatives. They can complement each other.



B) Interlinking with BPO and CRM

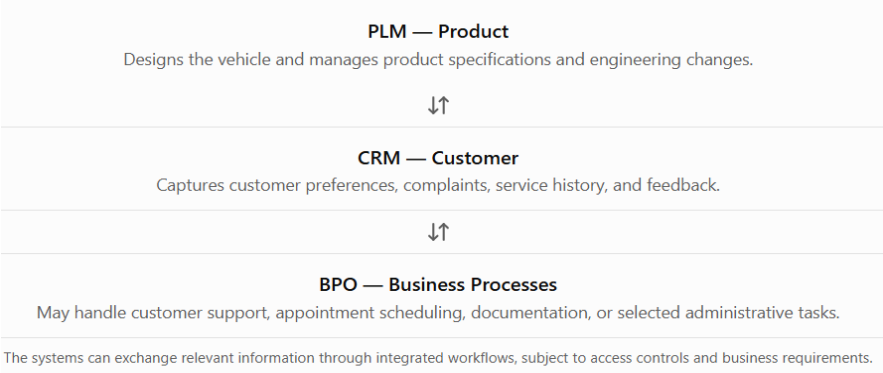
BPO — Business Process Outsourcing
A business practice in which an organisation contracts another company to perform selected business processes.
Focus: Operational efficiency, service delivery, and cost management.
Examples: Customer support, payroll processing, accounting, and data entry.

CRM — Customer Relationship Management
A strategy and set of tools for managing customer information, interactions, sales, marketing, and service.
Focus: Customer satisfaction, retention, and revenue growth.
Examples: Lead management, sales forecasting, complaint tracking, and customer loyalty.

PLM — Product Lifecycle Management
An approach to managing product information, processes, and decisions from initial concept through design, production, service, and end of life.
Focus: Product innovation, quality, lifecycle cost, and sustainability.
Examples: Engineering change management, product configuration, bills of materials, and product traceability.

How BPO, CRM, and PLM work together

Consider an automobile manufacturer.



For example, customer complaints recorded in CRM can inform product improvements through PLM. A BPO provider may handle the initial complaint process, escalating technical issues to the manufacturer's service or engineering team.

Effective 360° PLM Strategies – Defining Strategy for Optimisation

A 360° Product Lifecycle Management (PLM) Strategy is a holistic and integrated management approach that coordinates people, processes, product data, technologies, enterprise systems, regulatory requirements, and sustainability objectives within a unified framework to manage and optimise a product throughout its entire lifecycle. It encompasses all stages,



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from idea generation, conceptualisation, and product design to manufacturing, distribution, customer service, maintenance, and end-of-life recovery, reuse, or recycling.

The strategy aims to optimise product performance, cost, quality, time, resource utilisation, regulatory compliance, and environmental sustainability through effective integration, cross-functional collaboration, data-driven decision-making, and continuous performance improvement.

Furthermore, it establishes a continuous optimisation and adaptive feedback cycle in which product data, interconnected business systems, stakeholder collaboration, analytics, and performance feedback are systematically used to identify inefficiencies, evaluate improvement opportunities, support intelligent decisions, and adapt product-related processes to changing business and market conditions.

MAJOR PLM STRATEGIES

1. Product innovation strategy

Develop new products and improve existing products using market research, engineering knowledge, customer feedback, and emerging technologies.

Key measures: New product success rate, development time, innovation revenue.

2. Product data integration strategy

Create a consistent source of product information across engineering, manufacturing, procurement, finance, and service.

Key measures: Data accuracy, duplicate records, engineering change turnaround time.

3. Manufacturing and operational optimisation

Align product design with production capabilities, standardise processes, and use manufacturing feedback to reduce defects and rework.

Key measures: First-pass yield, production cost, scrap rate, time-to-market.

4. Digital and AI-driven PLM

Integrate PLM with AI, IoT, digital twins, and analytics to predict failures, evaluate design alternatives, and improve lifecycle decisions.

Key measures: Prediction accuracy, downtime, decision lead time, realised benefits.

5. Sustainable lifecycle strategy

Consider material selection, energy consumption, repairability, reuse, recycling, and environmental impact from the design stage onward.

Key measures: Lifecycle emissions, material recovery, waste, product lifespan.

6. Sell and Service Strategies

Sales and service strategies are important components of PLM because they connect the product with customers before purchase, during ownership, and after the sale. They help organisations increase revenue, improve customer satisfaction, strengthen loyalty, and use customer feedback to improve future products.

6.a Sales strategies

6.a.1. Customer-centric selling

Identify customer needs and recommend products based on their requirements, applications, and budget.

Measure: Customer conversion rate and satisfaction.

6.a. 2. Data-driven sales strategy

Use CRM data, sales trends, customer behaviour, and demand forecasts to improve sales planning and product positioning.

Measure: Sales growth, forecast accuracy, and conversion rate.

6.a.3. Product configuration and personalisation

Offer product options that meet different customer requirements while maintaining control over approved configurations, components, and specifications.

Measure: Order accuracy, configuration time, and product margin.

6.a.4. Relationship and lifecycle-value selling

Develop long-term customer relationships through upgrades, accessories, service agreements, replacement parts, and product improvements.

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Measure: Customer retention, repeat purchases, and lifetime customer value.

6.b. Service strategies

6.b.1 . Preventive and predictive maintenance

Schedule maintenance or predict equipment failures using operating data, service history, and condition monitoring.
Measure: Downtime, failure rate, and maintenance cost.

6.b.2 . Responsive customer support

Establish effective complaint handling, troubleshooting, warranties, technical assistance, and escalation procedures.
Measure: Resolution time, first-contact resolution, and customer satisfaction.

6.b.3. Digital service and product traceability

Connect service records with product specifications, serial numbers, component revisions, and maintenance instructions.
Measure: Service accuracy, traceability, and repeat fault rates.

6.b.4. Lifecycle extension and upgrade services

Extend product life through repairs, upgrades, refurbishment, remanufacturing, and spare-parts management.
Measure: Product lifespan, repair success, and recovery value.

7.Customer acquisition and Retention Strategies

Customer acquisition and retention are two complementary business strategies that help organisations grow, improve profitability, and build long-term customer relationships. In the context of CRM, BPO, and Product Lifecycle Management (PLM), acquisition focuses on attracting new customers, while retention focuses on keeping existing customers satisfied, loyal, and profitable.

7.A Customer Acquisition Strategies

Customer acquisition refers to the processes and activities used to identify, attract, convert, and onboard new customers.

1. Digital marketing and lead generation

Use search engine optimisation, social media, online advertising, content marketing, and email campaigns to attract potential customers.

2. Targeted selling and segmentation

Classify prospective customers by needs, purchasing power, industry, demographics, or behaviour and offer relevant products or services.

3. Referral and partnership strategy

Encourage existing customers to recommend the company and build partnerships with distributors, suppliers, and complementary businesses

4. Product differentiation and value proposition

Demonstrate how the product solves customer problems through product trials, demonstrations, competitive pricing, quality, and after-sales support.

7.B. Customer Retention Strategies

Customer retention involves maintaining customer relationships, encouraging repeat purchases, reducing customer attrition, and increasing long-term customer value.

1. Personalised customer relationship management

Use CRM data to understand purchase history, preferences, complaints, and service requirements. Provide personalised communication and offers.

2. Loyalty and rewards programmes

Offer loyalty points, membership benefits, repeat-purchase incentives, renewal benefits, and appropriate discounts.

3. Service quality and complaint resolution

Provide responsive support, transparent communication, effective complaint handling, warranties, maintenance, and timely service.

4. Customer feedback and continuous improvement

Analyse reviews, surveys, complaints, and usage patterns to improve products, services, and customer experience.

Measuring Strategies effectiveness

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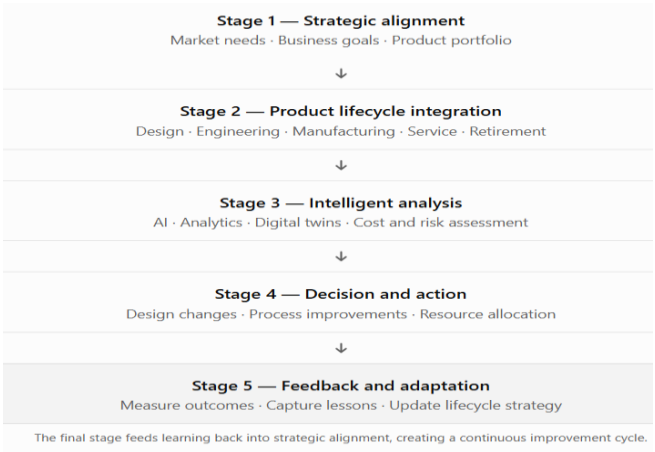
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The following indicators can be used to assess whether acquisition and retention strategies are working.

Metric	Formula
Customer acquisition cost (CAC)	Acquisition expenditure ÷ New customers acquired
Conversion rate	Customers acquired ÷ Qualified leads × 100
Customer retention rate	$\frac{E-N}{S} \times 100$
Customer churn rate	Customers lost during period ÷ Customers at start × 100
Customer lifetime value (CLV)	Estimated net value of a customer over the relationship
Repeat purchase rate	Customers making repeat purchases ÷ Customers purchasing × 100

In the retention formula, (E) is the number of customers at the end of the period, (N) is the number of new customers acquired during the period, and (S) is the number of customers at the start.

A comprehensive strategy should connect business objectives, product data, lifecycle operations, and feedback.



PLM strategies implementation

1. **Assess the current state:** Examine product development processes, data quality, systems, and organisational capabilities.
2. **Set measurable objectives:** Define targets for cost, quality, innovation, sustainability, and time-to-market.
3. **Establish governance**: Assign ownership of product data, engineering changes, and lifecycle decisions.
4. **Integrate systems:** Connect PLM with relevant CAD, ERP, manufacturing execution, CRM, and service systems.
5. **Develop cross-functional teams:** Coordinate engineering, manufacturing, finance, IT, marketing, and customer service.
6. **Introduce analytics progressively**: Start with a clear business problem before adding AI or digital twin capabilities.
7. **Evaluate and adapt:** Compare actual results with baseline performance and revise the strategy based on evidence.

PLM Workflow Management

PLM Workflow Management (Product Lifecycle Management Workflow Management) is the systematic design, coordination, automation, and monitoring of tasks, approvals, information, and responsibilities associated with a product throughout its lifecycle.

It ensures that the right people receive the right product information at the right time, following defined procedures and approval rules.

For example, when an engineer modifies a product design, a PLM workflow can automatically route the change to engineering, quality, manufacturing, and management for review and approval before the revised design is released for production.

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1. Major PLM workflows

1. **Product design workflow**

Manages design creation, document submission, technical review, revision, and design approval.

2. Engineering Change Management (ECM)

Controls change requests, impact analysis, approvals, implementation, and revision history.

3. Bill of Materials (BOM) workflow

Coordinates the creation, validation, approval, and release of product structures and component lists.

4. Quality and compliance workflow

Routes inspections, nonconformance reports, corrective actions, and required compliance documentation.

5. Manufacturing release workflow

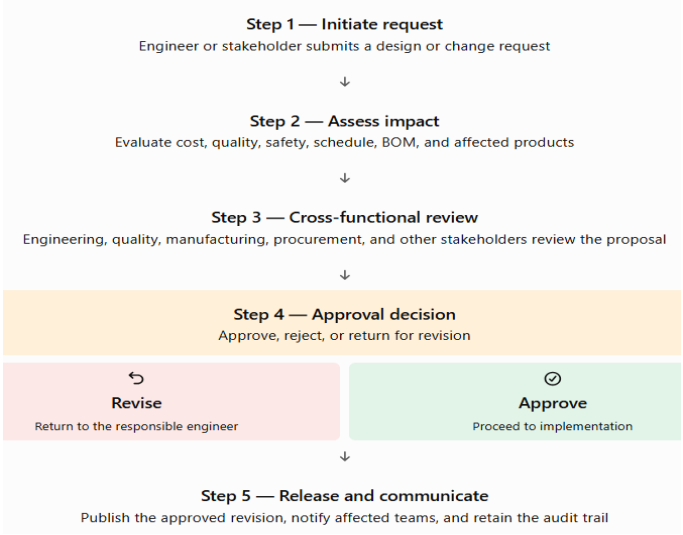
Ensures approved designs, BOMs, work instructions, and related documents are available before production begins.

6. Service and end-of-life workflow

Coordinates maintenance feedback, product improvements, spare parts information, product retirement, and disposal documentation.

PLM workflow management process

The following illustrates a typical product change workflow.



Essential components of PLM workflow management

Component	Function
Workflow rules	Define task sequences, conditions, and decision points
Roles and responsibilities	Assign tasks to engineers, managers, quality teams, and approvers
Document and version control	Maintain approved documents and revision history
Approval management	Apply approval hierarchies and authorisation rules
Notifications and escalations	Alert users about pending or overdue tasks
Audit trail	Record actions, decisions, timestamps, and changes
Integration	Connect PLM with CAD, ERP, CRM, MES, and supplier systems
Performance monitoring	Track cycle times, bottlenecks, rework, and workflow completion

Key performance indicators (KPIs)

PLM workflow effectiveness can be measured using the following indicators.

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KPI	Measurement
Workflow cycle time	Time from workflow initiation to completion
Approval lead time	Time spent awaiting required approvals
First-pass approval rate	Requests approved without rework ÷ total requests × 100
Change implementation time	Time from approved change to completed implementation
Workflow compliance	Workflows following required procedures ÷ workflows assessed × 100
Rework rate	Workflows returned for correction ÷ total workflows × 100
On-time completion	Workflows completed by deadline ÷ workflows due × 100

These KPIs help identify where delays occur and whether workflow automation is improving productivity.

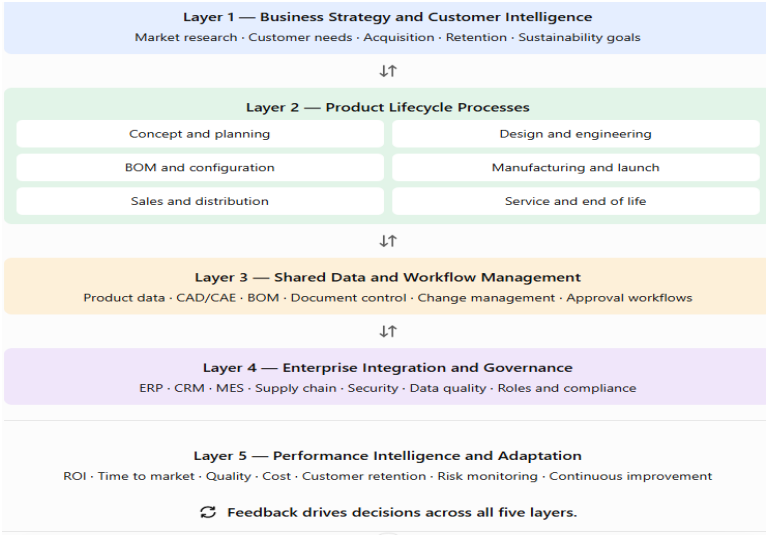
PLM FRAMEWORK

A Product Lifecycle Management (PLM) framework is an integrated structure of processes, people, data, technologies, and governance mechanisms used to manage a product from initial market research and concept development through design, manufacturing, sales, service, and end-of-life management.

The objective is to ensure that product-related decisions are coordinated across departments, product information remains consistent, and business performance improves throughout the product lifecycle.

For your research interests in PLM strategy, workflow management, implementation challenges, ROI, customer acquisition, and retention, a useful direction is an integrated, adaptive, data-driven PLM framework.

Proposed integrated PLM framework



Seven stages of the PLM framework

Stage 1: Market intelligence and product planning

Identify customer needs, market opportunities, competitors, target costs, and product requirements.

Stage 2: Product design and engineering

Develop product concepts, specifications, CAD models, prototypes, and engineering designs.

Stage 3: Product data and configuration management

Manage BOMs, product versions, engineering documents, component relationships, and design changes.

Stage 4: Manufacturing and launch

Coordinate production readiness, quality approvals, supplier requirements, and product release.

Stage 5: Sales and customer acquisition

Use product information to support customer proposals, product configuration, marketing, and sales.

Stage 6: Service and customer retention

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Capture maintenance records, complaints, warranty information, product performance, and customer feedback.

Stage 7: End-of-life and lifecycle learning
Manage repair, reuse, recycling, retirement, and lessons that inform future product development.

Framework Core components and their functions

Component	Main responsibility
Product data management	Maintain accurate and controlled product information
Workflow management	Coordinate tasks, approvals, and responsibilities
Change management	Control engineering changes and product revisions
Enterprise integration	Connect PLM with ERP, CRM, MES, and supplier systems
Governance and security	Establish ownership, access controls, traceability, and compliance
Customer intelligence	Incorporate sales, service, and customer feedback
Performance analytics	Evaluate productivity, cost, quality, and ROI
Adaptive decision support	Recommend improvements based on performance data

How to implement the framework

- **Assess organisational readiness**. Identify business problems, existing systems, data quality issues, and stakeholder requirements.
- **Define the target architecture**. Establish lifecycle processes, system integrations, data ownership, and governance rules.
- **Prioritise workflows**. Begin with high-impact processes, such as design approvals, BOM control, or engineering change management.
- **Implement a pilot**. Test the framework with a selected product line or manufacturing unit.
- **Measure results**. Compare baseline performance with results after implementation.
- **Scale and adapt.** Expand successful processes and use performance feedback to refine the framework.

Measuring PLM framework effectiveness

KPI	What it evaluates
Time to market	Speed of product development and launch
Engineering change cycle time	Efficiency of change workflows
First-pass approval rate	Quality of submissions and process readiness
Product defect rate	Product quality
Data accuracy	Reliability of product information
User adoption rate	Extent to which employees use PLM workflows
Customer retention rate	Ability to maintain customer relationships
PLM ROI	Financial return relative to implementation and operating costs

PLM IMPLEMENTATION CHALLENGES

Product Lifecycle Management (PLM) implementation challenges are the technical, organisational, financial, and strategic difficulties an organisation faces when integrating product-related data, processes, people, and technologies across the complete product lifecycle.

A PLM system may connect product design, engineering, manufacturing, procurement, sales, customer service, and end-of-life management. Implementation is therefore not merely a software installation; it is an organisational transformation.

PLM Interdepartmental Communication

This makes the systematic exchange of product-related information, decisions, requirements, and feedback among departments throughout the product lifecycle. It ensures that all departments work with consistent product data, approved changes, and shared objectives.

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Department	Information shared	Receiving department(s)
R&D / Design	Product specifications, design revisions	Production, Quality, Procurement
Production	Capacity, process constraints, defects	Design, Quality, Planning
Quality	Inspection results, deviations, corrective actions	Production, R&D, Management
Procurement	Supplier performance, material availability	Production, R&D, Finance
Marketing / Sales	Customer requirements, demand forecasts	R&D, Planning, Management
Finance	Cost estimates, budgets, lifecycle costs	Management, R&D, Production
Service / Support	Field failures, warranty claims, feedback	R&D, Quality, Production

Major PLM implementation challenges

1. Data integration and migration

Product information may be scattered across CAD tools, ERP systems, spreadsheets, legacy databases, and document repositories.

Impact: Duplicate records, missing information, inconsistent product versions, and costly migration.

2. Resistance to organisational change

Employees may prefer familiar workflows, resist new responsibilities, or perceive PLM as additional administrative work.

Impact: Low adoption, workarounds, and limited realisation of expected benefits.

3. Integration with existing systems

PLM must exchange information reliably with ERP, CRM, CAD/CAE, manufacturing execution systems, and supply-chain platforms.

Impact: Integration delays, interoperability problems, and inconsistent workflows.

4. High implementation cost and uncertain ROI

Costs include licences, consulting, infrastructure, data cleansing, customisation, training, integration, and ongoing support.

Impact: Budget overruns, delayed benefits, and difficulty justifying investment.

5. Process standardisation and change control

Departments may use different naming conventions, approval procedures, product structures, and engineering change processes.

Impact: Bottlenecks, incorrect product releases, rework, and weak traceability.

6. Skills, training, and user adoption

Users require training in PLM workflows, product data governance, role-based access, and system-specific tools.

Impact: Low system utilisation, errors, and dependence on a small number of experts.

7. Data security and intellectual property protection

PLM can contain sensitive product designs, manufacturing specifications, and supplier information shared across organisational boundaries.

Impact: Unauthorised access, intellectual property exposure, and compliance risks.

8. Supplier and cross-functional collaboration

Suppliers, design teams, production units, and service teams may use different systems and data standards.

Impact: Delayed information exchange, supplier coordination problems, and lifecycle visibility gaps.

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PLM implementation challenges and mitigation strategies

Challenge	Recommended strategy	Performance indicator
Data quality	Data cleansing, master data standards, migration validation	Data error rate
Change resistance	Change management and stakeholder participation	User adoption rate
System integration	API-based integration and interoperability standards	Integration failure rate
High cost	Phased implementation and benefits tracking	PLM ROI, budget variance
Process complexity	Standardised workflows and change-control procedures	Engineering change cycle time
Skills gap	Role-based training and continuous support	Training completion and proficiency
Security risks	Access controls, audit trails, encryption, governance	Security incidents
Supplier coordination	Shared standards and controlled collaboration	Supplier response time

PLM & REGULATIONS

As PLM have been used widely for product management and hence has to go with multiple standards and processes as per the norms of countries and trade zones and hence it makes audit easier to the auditors and companies focuses on the core innovation and development activities. Auditors can report the expected future values of the product and its valuation. Thus, PLM helpful for keeping all the essential activities & document for audits as ease to access.

PLM and regulations refer to the processes, technologies and controls used to ensure that a product complies with applicable laws, industry standards, safety requirements and environmental obligations throughout its lifecycle.

Regulatory compliance is a key PLM driver because products must often satisfy requirements during design, manufacturing, distribution, operation, maintenance and end-of-life disposal.

Major regulatory areas relevant to PLM

Regulatory area	What PLM helps manage
Product safety	Safety requirements, risk assessments and test evidence
Quality management	Controlled procedures, inspection records and corrective actions
Environmental compliance	Restricted substances, waste, recyclability and environmental data
Material and chemical compliance	Material declarations and supplier substance information
Industry-specific requirements	Aviation, automotive, medical devices, electronics and other sector-specific obligations
Data protection and cybersecurity	Access controls and protection of sensitive product or customer information where applicable
Product traceability	Product configurations, serial numbers, batches and change histories
Export controls	Restricted technical data, access permissions and relevant export records

PLM regulatory compliance workflow

1. Identify applicable regulations
2. Map regulations to product requirements
3. Design and develop the product
4. Verify requirements through testing
5. Record evidence and obtain required approvals
6. Release the product under controlled conditions
7. Monitor changes in regulations and product performance

How PLM supports regulatory compliance

A well-designed PLM system can provide:

- **Requirements traceability:** connect each applicable regulation to design requirements and verification evidence.
- **Document control:** maintain approved versions of specifications, certificates and test reports.

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- **Change impact analysis:** identify which products, materials, suppliers and documents may be affected by a regulatory change.
- **Audit trails:** record approvals, revisions and responsible personnel.
- **Supplier compliance management**: collect and review material declarations and supporting evidence.
- **Lifecycle monitoring:** manage relevant compliance information after product release, including updates and end-of-life obligations.

Why PLM Projects Fail

Product Lifecycle Management (PLM) projects fail when organisations cannot align technology, business processes, product data, people, and strategic objectives. Installing PLM software alone does not guarantee success. The organisation must integrate its systems, standardise workflows, manage change, and measure business outcomes.

PLM projects can fail for various reasons, including:

1. Major reasons for PLM project failure

1. Lack of clear business objectives

Organisations implement PLM without defining measurable goals, such as reducing product development time, engineering costs, or product defects.

Result: The project delivers software functionality without sufficient business value.

2. Poor product data quality

Duplicate records, outdated drawings, inconsistent BOMs, and incomplete legacy data complicate migration and daily operations.

Result: Incorrect decisions, rework, and reduced trust in the PLM system.

3. Resistance to organisational change

Employees may resist new procedures, approval responsibilities, or unfamiliar software when training and communication are inadequate.

Result: Low adoption, shadow spreadsheets, and workarounds outside PLM.

4. Weak integration with existing systems

PLM may not exchange data reliably with CAD, ERP, CRM, manufacturing execution systems, or supplier platforms.

Result: Information silos, duplicate entry, and inconsistent product records.

5. Unrealistic budgets and timelines

Project plans underestimate data cleansing, customisation, integration, testing, training, and ongoing support.

Result: Budget overruns, delayed deployment, and reduced expected ROI.

6. Excessive customisation and process complexity

Organisations reproduce every legacy procedure in the new system instead of simplifying workflows and adopting appropriate standard practices.

Result: Complex maintenance, costly upgrades, and slow approvals.

7. Weak leadership and unclear accountability

Senior management may fail to resolve departmental conflicts, assign process ownership, or provide adequate resources.

Result: Poor coordination and decisions delayed between departments.

8. Inadequate performance measurement

The organisation tracks installation milestones but fails to evaluate product quality, workflow efficiency, adoption, or financial benefits.

Result: Problems remain undetected and the business case cannot be validated.

Mitigating PLM project failure

a) PLM Checkpoints Across the Product Lifecycle

PLM checkpoints are critical review and approval points used to verify that a product meets its requirements before progressing to the next lifecycle stage.

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No.	PLM checkpoint	Key verification
1	Concept approval	Market need, feasibility, business case
2	Requirements review	Customer needs, specifications, regulatory requirements
3	Design review	Design quality, performance, safety
4	Prototype validation	Testing, verification, design corrections
5	Design freeze	Approved design, BOM, revision control
6	Manufacturing readiness	Process capability, materials, equipment, suppliers
7	Quality and compliance approval	Quality tests, validation evidence, regulatory compliance
8	Product launch approval	Production readiness, packaging, market readiness
9	Performance monitoring	Defects, reliability, customer feedback, cost
10	Lifecycle optimisation	Improvements, upgrades, reuse, recycling, or discontinuation

b) Failure Prevention Strategies

Prevention strategy	Practical action	Success indicator
Strategic alignment	Define a business case and measurable targets	Benefit realisation
Data readiness	Cleanse, standardise, and validate migrated data	Data error rate
Change management	Engage users early and provide role-based training	Active user adoption
Integration planning	Test interfaces and establish data ownership	Integration reliability
Phased deployment	Pilot high-value workflows before wider rollout	Milestone and budget performance
Process simplification	Standardise workflows before automation	Approval cycle time
Executive governance	Assign accountable owners and escalation procedures	Decision turnaround time
Continuous monitoring	Compare actual outcomes against baseline KPIs	ROI and operational improvement

Understanding PLM Returns

With the implementation of PLM systems, the organisation is interested to grab the returns by way of implementing various strategies few of returns are as follows

1. Financial returns

Reduced product development costs, lower rework expenses, improved margins, reduced inventory holding costs, and increased revenue from faster product launches.

2. Operational returns

Shorter engineering change cycles, faster approvals, fewer duplicated activities, improved resource utilisation, and higher manufacturing productivity.

3. Quality and compliance returns

Fewer defects, less scrap, better traceability, faster audits, fewer compliance-related delays, and reduced warranty claims.

4. Strategic and innovation returns

Faster time-to-market, more product reuse, improved innovation capacity, better forecasting, and stronger competitive positioning.

5. Sustainability returns

Reduced material waste, energy consumption, emissions, and end-of-life disposal costs, alongside increased reuse and recyclability.

Key financial formulas

a) PLM ROI – Return on Investment in Product Lifecycle Management

PLM ROI measures the financial and operational benefits an organisation gains from investing in Product Lifecycle Management (PLM) systems, processes, and technologies compared with the total cost of implementing and operating them.

PLM connects product data, design, engineering, manufacturing, sales, service, and end-of-life management throughout the product lifecycle. Its return on investment can come from reduced product development costs, faster time to market, fewer engineering errors, improved product quality, and better customer retention.

PLM ROI formula

$$\text{PLM ROI} = \frac{\text{Total Benefits} - \text{Total PLM Costs}}{\text{Total PLM Costs}} \times 100$$

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Benefits and costs should be measured over the same period, such as three or five years, and discounted to present value when appropriate.

How does PLM generate ROI?

Benefit area	Measurable indicator	Financial impact
Engineering productivity	Engineering hours per project	Lower labour costs or greater project capacity
Faster product development	Time-to-market	Earlier revenue generation
Design reuse	Reuse rate of components and designs	Reduced development costs
Quality improvement	Defect rate, rework, warranty claims	Lower quality-related expenditure
Change management	Engineering change order (ECO) cycle time	Less delay and rework
Supply chain integration	Inventory, procurement errors	Reduced operating costs
Customer retention	Repeat purchases, churn, customer lifetime value	Improved long-term profitability
Sustainability	Material waste, energy use	Lower resource costs

b) Payback period

Measures how long it takes for the investment to recover its initial cost.

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Annual Net Cash Benefit}}$$

This simple formula assumes a reasonably stable annual benefit. For uneven cash flows, calculate the cumulative cash flow year by year.

c) Cost savings

$$\text{Cost Savings} = \text{Baseline Cost} - \text{Current Cost}$$

Examples include reduced rework, engineering hours, material waste, inventory holding costs, and warranty expenses.

d) Net Present Value (NPV)

NPV considers the time value of money and is useful for evaluating long-term PLM investments.

$$NPV = -I_0 + \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

Where (I0) is the initial investment, (CFt) is the net cash flow in year \(t\), and \(r\) is the discount rate. A positive NPV indicates that projected returns exceed the required rate of return under the model's assumptions.

Other useful PLM return indicators

Performance area	KPI	Measurement
Development	Product development time	Baseline days – current days
Engineering	Change processing time	Average days per approved change
Quality	Defect rate	Defective units ÷ total units × 100
Productivity	Engineering productivity	Output per engineering hour
Data	Product data accuracy	Correct records ÷ records audited × 100
Integration	System integration reliability	Successful transactions ÷ total transactions × 100
Customer	Customer satisfaction	Survey score or customer retention
Compliance	Traceability coverage	Requirements with complete evidence ÷ applicable requirements × 100
Sustainability	Material waste reduction	Baseline waste – current waste
Innovation	Time-to-market	Time from approved concept to market launch

Future of Product Lifecycle Management

The future of Product Lifecycle Management (PLM) is moving from traditional product data management towards intelligent, connected, predictive, and adaptive product lifecycle management. Emerging technologies such as artificial



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intelligence (AI), digital twins, the Industrial Internet of Things (IIoT), cloud computing, and generative design are changing how organisations design, manufacture, sell, maintain, and retire products.

The next generation of PLM will not simply store product information. It will help organisations predict problems, optimise decisions, personalise products, improve customer retention, and measure sustainability and financial performance across the entire product lifecycle.

Major trends shaping the future of PLM

1. AI-powered and generative PLM

AI can help automate engineering tasks, analyse product requirements, identify design alternatives, classify documents, and predict product quality issues.

Future impact: Faster design cycles, improved decision support, and reduced repetitive work.

2. Digital twins and connected products

Digital twins connect virtual product models with operational data from physical products, enabling simulation, performance monitoring, and predictive maintenance.

Future impact: Better reliability, fewer unexpected failures, and continuous product improvement.

3. Cloud-based collaborative PLM

Cloud platforms can help distributed engineering teams, suppliers, and manufacturers collaborate using shared product information and controlled workflows.

Future impact: Improved collaboration, scalability, and access across locations.

4. Real-time and IoT-integrated PLM

Data from products in operation and connected manufacturing equipment can inform engineering and service decisions.

Future impact: Faster fault detection, better service planning, and evidence-based redesign.

5. Sustainable and circular PLM

Product lifecycle systems can track materials, energy use, repairability, reuse, recycling, and environmental impacts.

Future impact: Lower material waste, improved resource efficiency, and better lifecycle sustainability assessment.

6. Customer-centric PLM

CRM, sales, warranty, service, and customer feedback data can be connected to product development and improvement processes.

Future impact: More relevant products, improved service, and stronger customer retention.

PLM Success Stories

1. Polaris — Automotive and powersports

Digital integration - Polaris used PTC Windchill to connect engineering, manufacturing, sales, and service data. Its PLM-enabled digital thread supports complex product variants, bill-of-materials management, change control, and more informed decisions using field and factory data.

Key lesson: A common product-data foundation helps manage product complexity and improve collaboration across the lifecycle.

2. Zamil Industrial — HVAC and industrial engineering

Zamil adopted cloud-based Windchill+ to support engineering collaboration, secure product information, and scalable systems. The company operates in India and Saudi Arabia.

Key lesson: Cloud PLM can support collaboration across locations and make it easier to scale product-development infrastructure.

3. ADB Broadband — Electronics

ADB Broadband adopted Windchill PDMLink and integrated it with its ERP system. The implementation included migration of components, documents, and bills of materials from legacy systems.

Reported outcomes: Improved product configuration, engineering change management, document management, and data sharing.

4. Liebherr — Heavy equipment

PTC describes how Liebherr Earthmoving is using connected product data to strengthen traceability, reduce rework, and build a foundation for scalable engineering processes.



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Key lesson: PLM is not only a design-data repository; it can help connect engineering decisions with downstream operational outcomes.

5. Generac — Power systems

Generac is featured in PTC's case studies for connecting engineering, manufacturing, and service through a unified digital foundation.

Key lesson: Lifecycle visibility becomes more valuable when product information is available beyond the engineering department, including during production and after-sales service.

CONCLUSION

Product Lifecycle Management (PLM) is evolving from a traditional product data management system into an intelligent, integrated, and adaptive business framework. By integrating Artificial Intelligence (AI), digital twins, real-time data analytics, cloud technologies, and workflow automation, organisations can improve product quality, reduce development costs, accelerate time-to-market, and enhance customer satisfaction.

A major opportunity lies in developing an adaptive, AI-driven PLM framework that continuously monitors product performance, identifies risks, predicts potential problems, recommends corrective actions, and learns from feedback. Such a framework can support operational efficiency, customer retention, sustainable product development, and long-term organisational competitiveness.

Ultimately, the success of future PLM will not be measured solely by technology adoption, but by its ability to transform product information into actionable intelligence and measurable business outcomes. Research should therefore focus on developing and empirically validating integrated PLM frameworks that balance technological innovation, organisational readiness, data governance, sustainability, and return on investment.

Before PLM, organisations often experience fragmented data, disconnected departments, manual workflows, and limited lifecycle visibility. After effective PLM implementation, they can establish integrated product information, traceable workflows, better collaboration, and measurable performance improvements. Gap analysis identifies the distance between current capabilities and desired outcomes, then converts that distance into a prioritised PLM implementation and improvement plan.

REFERENCES

[1] W. M. Cheung and D. Schaefer, "Product lifecycle management: state-ofthe-art and future perspectives," in Enterprise information systems for business integration in SMEs: Technological, organizational, and social dimensions: IGI Global, 2010, pp. 37-55.
[2] B. Carsten, "Product Lifecycle Management enables global network Innovation," 2007.
[3] A. Corallo, V. Del Vecchio, M. Lezzi, and A. Luperto, "Model-Based Enterprise Approach in the Product Lifecycle Management: State-of-theArt and Future Research Directions," Sustainability, vol. 14, no. 3, p. 1370, 2022, doi: 10.3390/su14031370.
[4] S. Takata et al., "Maintenance: Changing Role in Life Cycle Management," CIRP Annals, vol. 53, no. 2, pp. 643-655, 2004.
[5] M. Eigner, "Forty Years of Product Data Management from PDM via PLM to SysLM," Springer Fachmedien Wiesbaden, 2021, pp. 5-25.
[6] A. Hewett, "Product Lifecycle Management (PLM): Critical Issues and Challenges in Implementation," Springer US, 2010, pp. 81-105.
[7] S.-G. Lee, Y.-S. Ma, G. L. Thimm, and J. Verstraeten, "Product lifecycle management in aviation maintenance, repair and overhaul," Computers in industry, vol. 59, no. 2-3, pp. 296-303, 2008.
[8] J. Li, F. Tao, Y. Cheng, and L. Zhao, "Big Data in product lifecycle management," The International Journal of Advanced Manufacturing Technology, vol. 81, no. 1-4, pp. 667-684, 2015. [9] D. Gerhard, "Product Lifecycle Management Challenges of CPPS," Springer International Publishing, 2017, pp. 89-110.
[10] F. Tao, J. Cheng, Q. Qi, M. Zhang, H. Zhang, and F. Sui, "Digital twindriven product design, manufacturing and service with big data," The International Journal of Advanced Manufacturing Technology, vol. 94, no. 9-12, pp. 3563-3576, 2018.
[11] Bruno, G., Korf, R., Lentes, J., & Zimmermann, N. (2016). Efficient management of product lifecycle information through a semantic platform. International Journal of Product Lifecycle Management, 9(1), 45-64.



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[12] J. Gao, H. Aziz, P. Maropoulos, and W. Cheung, "Application of product data management technologies for enterprise integration," International Journal of Computer Integrated Manufacturing, vol. 16, no. 7-8, pp. 491-500, 2003.
[13] C. S. Sung and S. J. Park, "A component-based product data management system," The International Journal of Advanced Manufacturing Technology, vol. 33, no. 5-6, pp. 614-626, 2007. [17] F. Ameri and D. Dutta, "Product Lifecycle Management: Closing the Knowledge Loops," Computer-Aided Design and Applications, vol. 2, no. 5, pp. 577-590, 2005, doi: 10.1080/16864360.2005.10738322.
[15] Brunsmann, J., Wilkes, W., Schlageter, G., & Hemmje, M. (2012). State-of-the-art of long-term preservation in product lifecycle management. International Journal on Digital Libraries, 12(1), 27-39.
[16] T. O. Ayodele, "Types of machine learning algorithms," New advances in machine learning, vol. 3, pp. 19-48, 2010.
[17] M. Bhat, K. Shumaiev, A. Biesdorf, U. Hohenstein, and F. Matthes, "Automatic Extraction of Design Decisions from Issue Management Systems: A Machine Learning Based Approach," Springer International Publishing, 2017, pp. 138-154.
[18] X. Yao, S. K. Moon, and G. Bi, "A hybrid machine learning approach for additive manufacturing design feature recommendation," Rapid Prototyping Journal, vol. 23, no. 6, pp. 983-997, 2017.
[19] Cai, H., Xu, L., & Xu, B. (2014). IoT-Based configurable information service platform for Product Lifecycle Management. IEEE Transactions on Industrial Informatics, 10(2), 1558-1567.
[20] J. Stark, "Product Lifecycle Management," Springer International Publishing, 2016, pp. 1-35.