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Digitization and management of product data through the PRO.FILE PLM system

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1 Declaration & Acknowledgement

I officially finish my academic career with this last step, the thesis and plan to enter full time in my professional career. The strong feelings of gratitude I have cannot be expressed in words. First of all, I would like to praise GOD that I am able to finish this milestone.

This work would not be possible without the constant support and timely guidance of my supervisor Professor Giulia Bruno. Her ideas, vision and assistance advanced me in the completion of this thesis for that I express my deepest appreciation. I would also like to thank Stefano De Toni and all other colleagues of Cadtec Srl., who supported me from day one and made me feel like a part of the team, assisted me in exploring the field of PLM and prepared me side by side for the professional career while I was working on this thesis.

Finally, I would like to pay a wholesome tribute to my parents Mr. & Mrs. Farooq for their constant love, care, and support. Thank you for supporting me in studying abroad and chasing my dreams.

2 Abstract

The pace of innovation is accelerating more than ever before. New technologies and digitalization are rapidly transforming how businesses all over the world operate — and product development companies are no exception.

Although it may seem daunting, digital transformation also presents huge opportunities for product development companies. Opportunities to stand out compared to the competition, and in the process, revolutionize how new products are designed, developed, and launched.

From agile ways of working to IoT, 3D printing, rapid prototyping, all the way to leveraging AI, digital transformation is having a huge impact on the field of product development. The product development discipline is adapting at lightning speed to feedback from the market and users.

In the midst of managing all this, is where the PLM software comes into play. The objective of this paper is to explore the various digitization and data management options, implementation and factors of PLMs in general and how PRO.FILE in specific is assisting the product development process with its philosophy and unique strategies to be more efficient and interactive through its state-of-the-art interactive DMS and PLM platform.

The paper also presents the challenges faced by clients in adopting PLM, by service providers like PRO.FILE in catering client needs and proposed solutions.

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5 Introduction

5.1 Digitization vs Digitalization

Digitization can be defined as the process for the transformation of data or information from a tangible form to a digital version. The term coined ‘digitize’ refers to anything which is non digital getting a digital representation that may be utilized for automating an operation or a workflow by a computer system.

The main aim of digitization is to enhance accessibility, storage, maintenance and sharing of information. Increasing the efficiency of business operations and automating the daily activities in organizations. (Devi, 2005)

Often used interchangeably with the term digitalization which is taking advantage of the digital technologies in transforming a company and inserting value-adding prospects.

As described by Clerck ‘’Digitalization is defined as the use of digital technologies and of data in order to create revenue, improve business, replace/transform business processes and create an environment for digital business, whereby digital information is at the core’’. (Clerck, 2017)

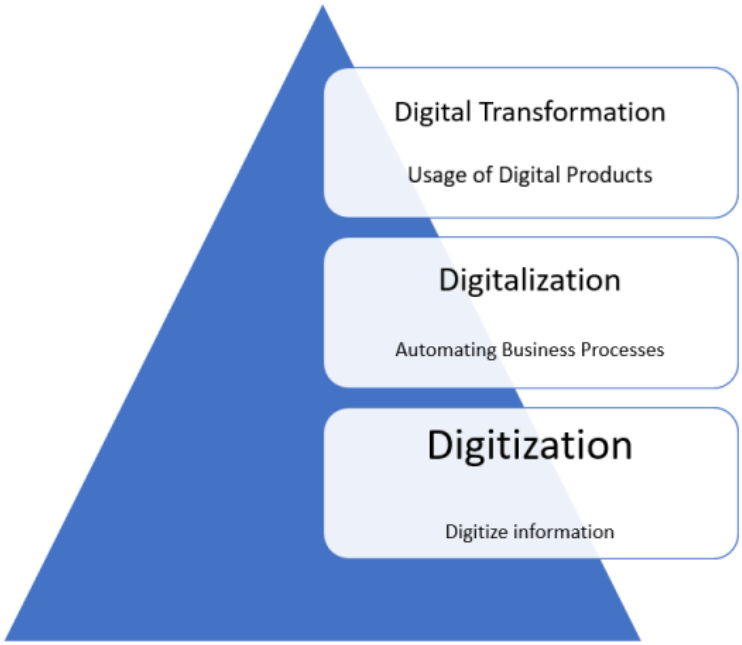


Figure 1 Digitization vs Digitalization

5.2 Product Data Management

Product Data Management abbreviated as PDM is one of the aspects of product lifecycle management (PLM). When digitized this is also known as ‘Version Control’. The objective is to ensure that the understanding of all stakeholders is aligned, to minimize confusions during the process execution, maintaining the quality controls standards.

Modern day practices of product development emphasize heavily on rapid yet uniformly informed activities and data management for which PDM is not sufficient alone and PLM software are a

necessity. Throughout the literature review we will discuss how data is managed in Product Life Cycle Management system and how the software is served as a service for users to rely on for product development.

Moving towards the exploration of PLM software named as PRO.FILE by company PROCAD its offerings, challenges faced in implementation and their resolution.

6 Literature Review

6.1 Product Life Cycle Management

Product life-cycle management (**PLM**) can be considered as the strategic progression in business management for a product going through phases of its life cycle. The product is sold in a different setting each time it progresses to a different phase of its life for example design to manufacturing to shipping, the environment is different over time and requires to be managed accordingly. (Dmytro Adamenko, 2020)

6.1.1 Product Life Cycle

Briefly discussing the PLC, it is a cyclic product development pattern, consisting of market introduction, growth to eventual maturing and finally declination. This cycle differs from product to product

In a short way a PLC follows:

1st Stage

Product Development: Introducing a new product; in this period all the research and development happens

2nd Stage

Product Growth: Now the product is more than an idea it is commercially produced, marketing is done, and launched. The demand and competition sees an increment.

3rd Stage

Product Maturity: The product has saturated; competitors are also present in market. Product is advertised to different segments, but it is not having significant impact on the demand.

4th Stage

Product Decline: Now the product is on the verge of obsoletion, it is losing the demand. (Udokporo, 2021)

As shown in the graph below:

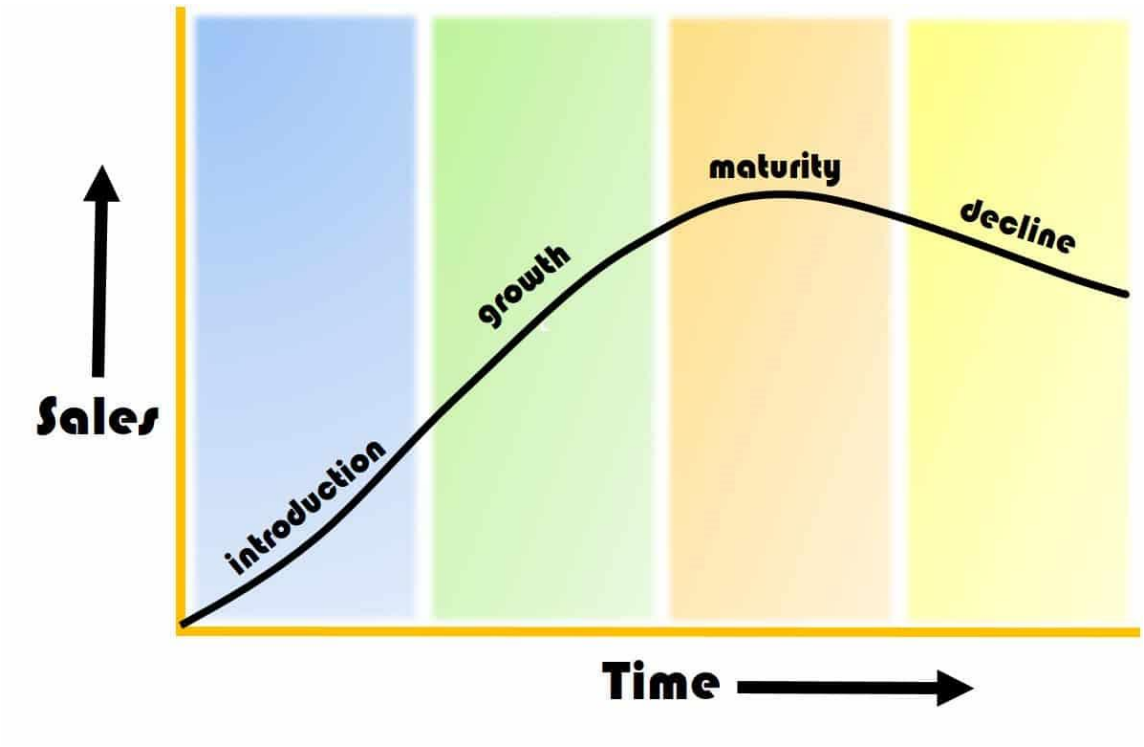


Figure 2 Product Life cycle

6.1.2 Adapting product delivery methods

Before diving into new product development methods, let's take a step back and examine where it all started.

Traditional new product development (also known as NPD) typically followed the **Waterfall model**. Requirements and specifications were exhaustively determined upfront, resources were estimated and budgeted, and a list of tasks was created that the development team needed to complete in order, without skipping ahead or working in parallel. In practice, the sequential cascade of development phases looks a lot like this:

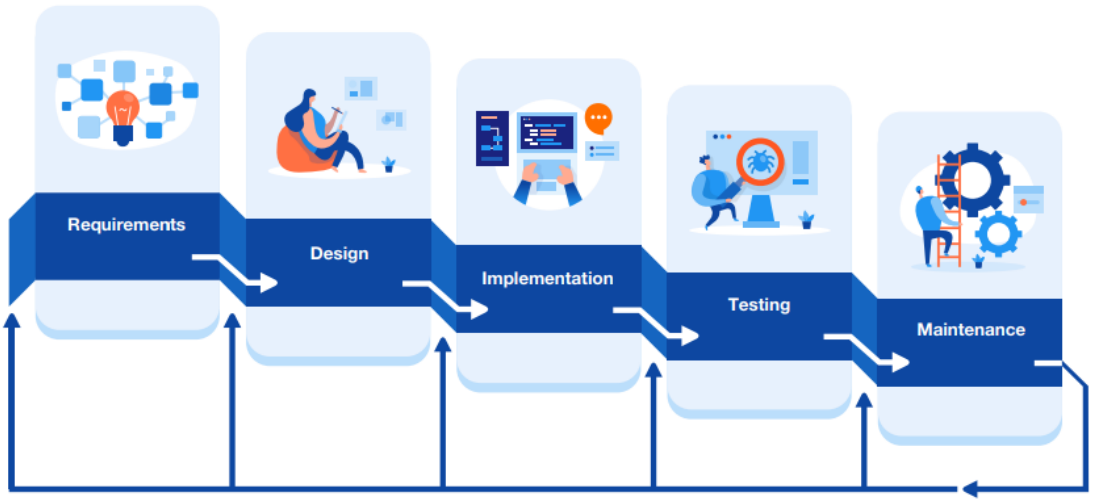


Figure 3 Waterfall Methodology

The downside of this development model is that it creates dependencies that slow down time to market. They also make it hard to adapt to unexpected challenges, and oftentimes, companies that use this model end up with a product that is not totally satisfactory to the customer because their feedback was not incorporated throughout the process. (Casteren, 2017)

This traditional Waterfall process has been reimagined for the digital age, resulting in the creation of **Agile methodologies**.

Agile and hybrid development methodologies promote:

- Close client collaboration, incorporating customer feedback throughout the process.
- Cross-functional, self-organizing teams Continuous learning, improvement, and process optimization.
- Flexible scope redefinition throughout the project.
- Iterative development sprints that allow teams to provide value more consistently, quickly, and safely Cross-functional, self-organizing teams.
- Continuous learning, improvement, and process optimization (Casteren, 2017)

As a result of implementing Agile ways of working, companies can respond much faster to new opportunities, manage shifting market and user demands, and stay competitive in an increasingly tough business ecosystem.

On top of that, many innovative technologies are also disrupting and revolutionizing the way product development methods are carried out, like:

- The use of artificial intelligence and machine learning to help with research, testing, predictive analytics.
- Computer-aided design programs to accelerate concepting and prototyping
- Augmented and Virtual Reality simulators for testing products that haven’t even been created yet
- Robotic assembly lines
- Embedded software and IoT for smart, connected devices and data collection. (N. Nozaki, 2017)

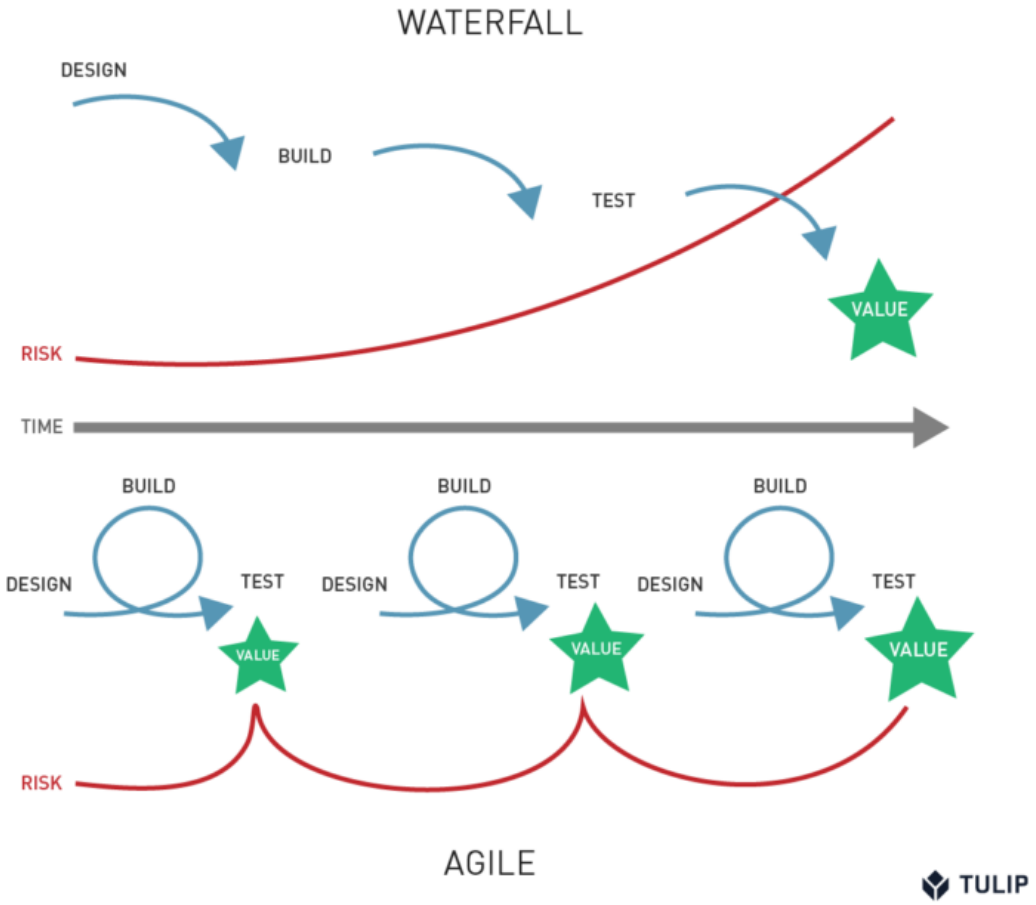


Figure 4 Agile methodology picturized by Tulip

6.1.3 Product Data Management

Product Data Management or PDM system can be defined as a repository of knowledge that is related to products & processes promoting exchange of information with security, integrating involved stake holders present in the value chain. (Brandao & Wynn, 2008)

In simpler terms it can be called a secure vault for saving CAD drawings, Bill Of Materials - BOM, models and more metadata of the respective item.

PDM was developed to handle revisions and modifications to engineering data, primarily data from CAD. Even while it can be used to control the design release process, in practical world there are various design-release processes that are happening outside the potential of PDM, that PDM as standalone is only a type of input to a bigger, more thorough process.

The typical main functionality of a PDM will be starting from :

Creating a Document: A document can be thought of as a container of information that is coming from various sources, several formats aligned with the needs of the organization.

Storage and retrieval: This involves use of a repository that stores all of these documents and allows the retrieval of them. It can be online and offline.

Management: This includes a broad range of effectively managing all documents like setting rules related to storage, verification of privileges, and managing configurations to meet the demands of the organization.

Version control: This is a method of recording document modifications and providing access to previous iterations of a document. (Wikramanayake, 2014)

Further discussion will be done on how a PDM is different from PLM and what drives the need for PLM.

A typical PDM system is shown below.

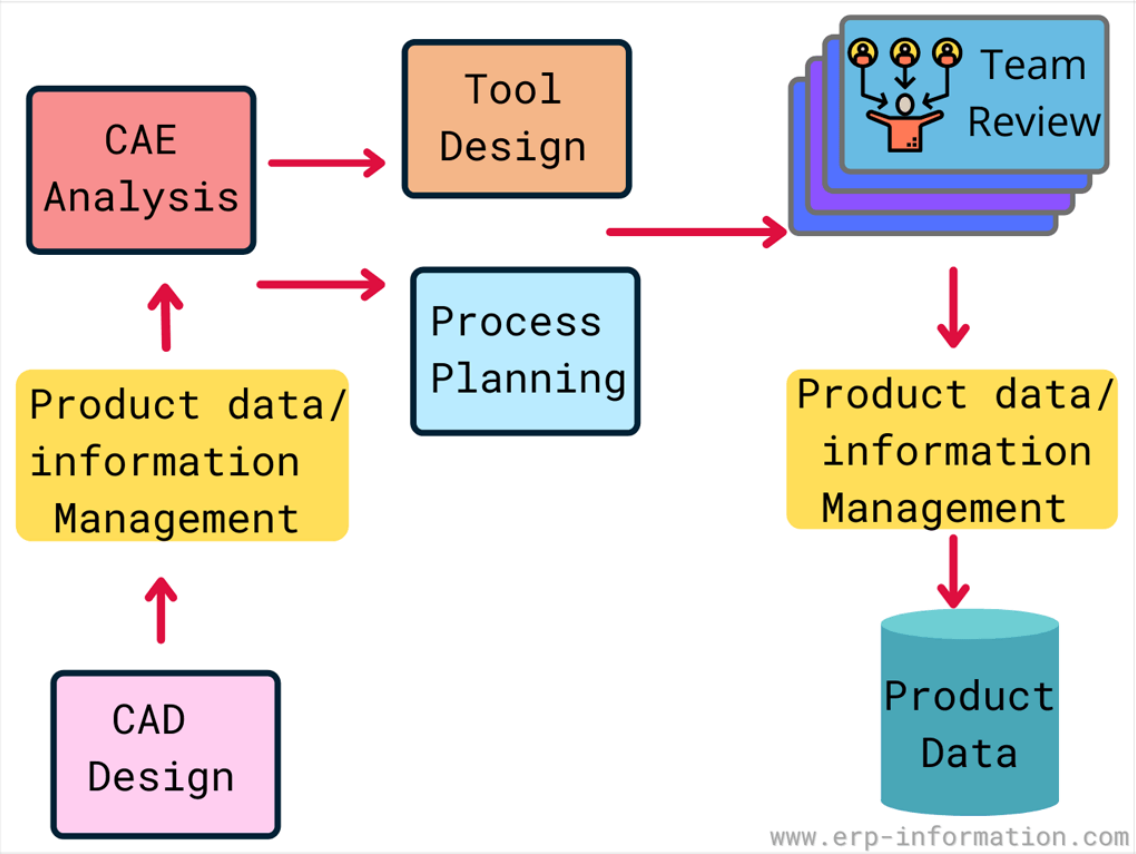


Figure 5 PDM flow of information

6.1.4 Product Life Cycle Management

American Motors Corporation (AMC) was not a big participant in the industry of automotive around 1980s. The organization was missing the financial source as of larger competitors of the market, this was becoming an obstacle for them to fully compete. The leaders at AMC had the idea of tracing the items/products phases from birth to end life so they can process them in a better way, hence competing efficiently– this is generally called the first step towards the product lifecycle.

This information that was being gathered was intended to be utilized for making sound and informed decisions in all the upcoming phases of a product – idea to all the way to procurement. The company started to experience a growth in market share, and it was later acquired by Chrysler which then lead to become the automotive's lowest cost producer by the mid-1990s. (Denger, 2021)

Now, PLM is being adopted in all different sectors to improve collaborative work, increase innovation, and support growth throughout crafting phase to customer demand and individualization of products (Javvadi, 2015).

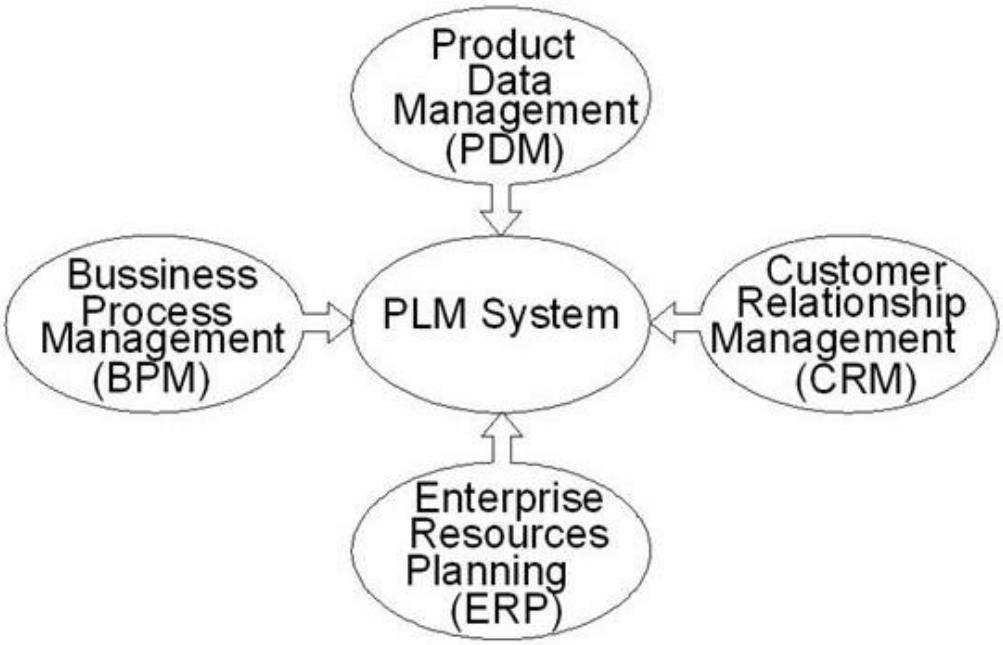


Figure 6 PLM overview

7 PLM Software

7.1 History and Early Stages – From CAD to PLM

PLM which we are aware of as of today started as the solution for the early product development and with the development of the computer-aided design (CAD) software. Those early solutions were useful but for that being only after that the industry faced another big problem which was the management, distribution, searching, and reuse these hefty CAD files. Earlier in those times the desktop machines were not designed for archiving massive amounts of CAD files let alone allowing the sharing between workers. (Emanuela AS, Eynard, & Nathan, 2014)

So now, Product data management (PDM) was established to overcome these hassles. Before 1990, PDM now also sometimes referred to as the PLM 1.0 assisted in CAD-centric solutions and the focus was almost completely on CAD save-files or related document management. It rapidly evolved into the scope of controlling the Distinta di Base or B.O.M (bill of material) and engineering change processes (ECOs) but the focus revolved around the product development.

During the nineties, globalizing the market, outsource, working with the time-to-market pressure pushed the organizations to further grow the scope of their current deployments of PDM.

The start of PLM introduced collaborative features and security options, it helped with its various functions in the major phases of the PLC, for instance along with manufacturing, product compliance, costing, and others to confront the problems that lie further after the core product development. There is no denying that PDM was still the core beginning of a PLM strategy, the options and tools were not really complete in the sense of providing assistance and reported to be difficult to use – nonuser friendly, and for customizing it required lengthy time-consuming procedures which were definitely not cost effective. (Emanuela AS, Eynard, & Nathan, 2014)

Early 2000s, the PLM developed, and this new development was product launch focused and instilled with more capabilities ranging along the lifecycle enclosing innovation management and requirements management, enhanced links with manufacturing line downstream, the supply chain, and commercializing. Mostly, these new options were systemized and still integrated with legacy tools. Even though the organizations enabled to leverage for these new features, this legacy approach still had complexities and needed extensive customization. (Javvadi, 2015)

Concurrently, pressures that pushed the starting progression of PDM and beginning PLM solutions grew. Business market required measures to satisfy the requirements product and process innovation demands, also the recent Industry 4.0 and digital-business transformation activities. (Stark J. , PLM, Facilities and Equipment, Industry 4.0, 2020)

Today, modern PLM software, is developed around software as a service (SaaS) model so companies no longer have the need to recruit big staffs of IT to regulate them.

7.1.1 Software as a Service (SaaS)

Software as a service, or commonly known as SaaS, is a methodology of providing programs over the internet. The term as-a-service in SaaS signifies that the company itself don't have to care installations, renewals, or maintenance of the software. But they just have the access to the service needed and the fees is paid for only those services that they use. (Chou & Chou, 2008)

With this new PLM - 4.0, companies can link and monitor a digitally, the many connections like the voice-of-machine (IOT Internet of Things), products (including digital twins), factory, and clients (via social monitoring) across the enterprise. Accessible from anywhere, anytime, it goes ahead breaking the obstacles of data silos and removes the complex accumulation of data across

supply networks. This means faster innovation, improved capabilities of decision making, better TTM (time to market), cost friendliness, and increased quality of products.

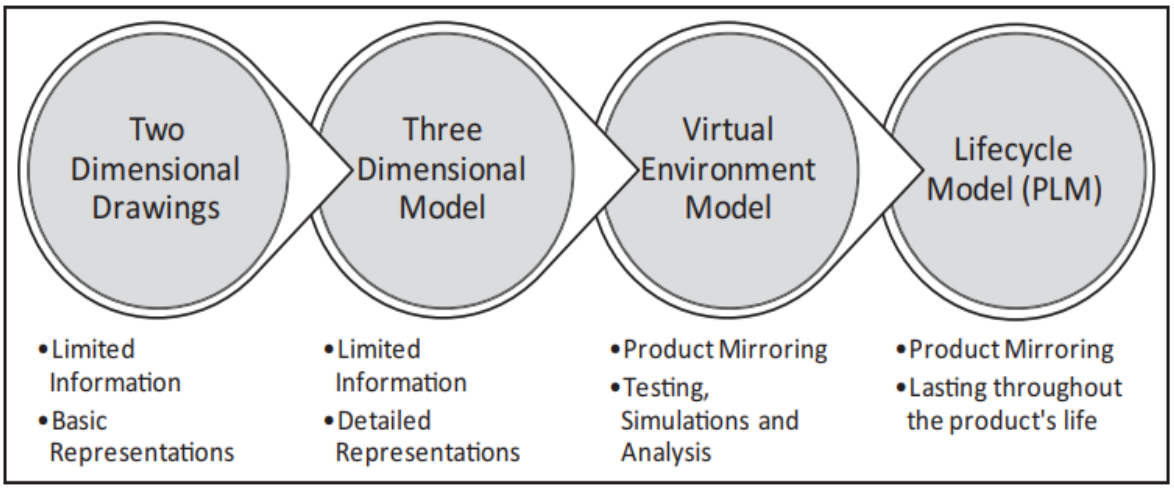


Figure 7 Evolution of PLM systems

7.2 Industry 4.0 & PLMs

7.2.1 History of Industry 4.0

For arriving at the stop of Industry 4.0 in the industrial revolution we have to take a quick walk along the history and continuous evolvement from first industrial revolution.

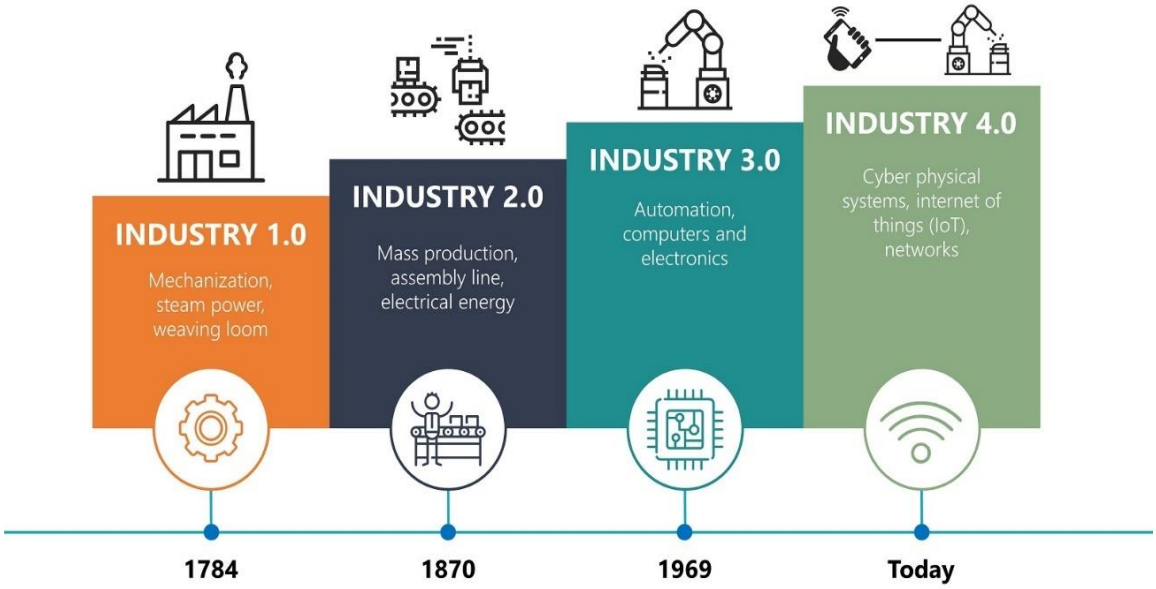


Figure 8 Historical Evolution of Industry 4.0

7.2.1.1 First Industrial Revolution

The First Industrial Revolution occurred until the late 1800s, bringing about significant changes, such as the expansion of factory production to countries beyond England and the development of transportation and communicating, it added railways systems, telegraph, and the system of navigating by steamboat technology. These innovations enhanced cross-border activities and integrated commerce into the logic of business expanding.

7.2.1.2 Second Industrial Revolution

This is also known as Technological Revolution, it followed serial events of innovation in the sectors related to industry of chemical, electric, metal industry and improvement in the sector of petroleum. This era was more involved in the finding of new sources for usage as raw materials and working on electrical supply. It focused on mass producing items, assembly lines, steam powering the sea transportation. This was the era when UK, USA and from the European side French and Germans emerged as the industrial pioneers. This was also the time ownership of companies was revised from oligarchical ownerships was thought of to be widely distributed with more increasing emphasis to public distribution. This era is also remembered for initiating to prohibition of child labor and start of chalking out Labor Laws. (Longley, 2021)

7.2.1.3 Third Industrial Revolution

The third industrial revolution was highly responsible of development of instruments for financial analysis of economy and termed as Market Economy. It expedited the usage of media and improvement of transportation for globalization. The rise of electronics, telecom, microelectronic components, computers and CNC(computerized numerical controlling). The hiring of people was on its high IR3's later half was also observed to start researching on nuclear resources as well as concepts of solar power.

7.2.1.4 The Fourth Industrial Revolution

As of today we are witnessing IR4 which is driven by information communication and technology ICT and cyber physical systems CPS. It has restructured the typical assembly lines and heavily relied on non-central controlling and superior connectivity.

In 2006 the government of Germany addressed in an annual trade fair Hannover Messe, regarding their high technology strategy. They defined it as an aim to strive for creative production alongside the technological advancement. They conveyed goals related to industrial development by higher points of personalization and automation. The term was first coined by the German scientists Dr. Wolfgang Wahlster, Dr. Kagerman that belonged to Deutsches Forschungszentrum für Künstliche Intelligenz, (DFKI) which is the German Research Center for Artificial Intelligence and Dr. Wolf Dieter who belonged to the Federal-Ministry of Research & Education. (Iotworlds, 2021)

In the beginning of 2014 german industries were checking their preparation for implementation of these strategies proposed by the government. Meanwhile 41% of german companies were already having knowledge of the Industrie 4.0 and were taking steps to initiate. On the other hand 44% of the specific companies which can be termed small scale companies were unaware of the Industrie 4.0 while the quantity in big scale who didn't act on Industrie 4.0 was only 17%. (Núbia Gabriela Pereira Carvalho, 2020)

The Industrie 4.0 practically guided in application of Internet of things (IoT), and connections being made in block formation so problems can be decentralized as well for their tracing and resolving. In IR4.0 focus was also on exploiting the software products for the manufacturing sector more and more like ERPs for resource planning in enterprises, digital mapping and MESs which is Manufacturing Execution Systems.

It also focused on data analysis of the machines and making it into useful information for insights and corrective optimization. It also merged with the concept put forward by a US corporation G.E(General Electric) for Industrial Internet.

7.2.1.4.1 Industrial Internet

Industrial Internet is the internconnection between data analysis specifically big data and Internet of Things. Applying them on metalevel networking functionality to systems that are distributed. (Techopedia, 2017)

The IIOT or Industrial Internet of Things basically formed a 5-layer architecture for decentralized interconnectivity. (Reis, 2018)

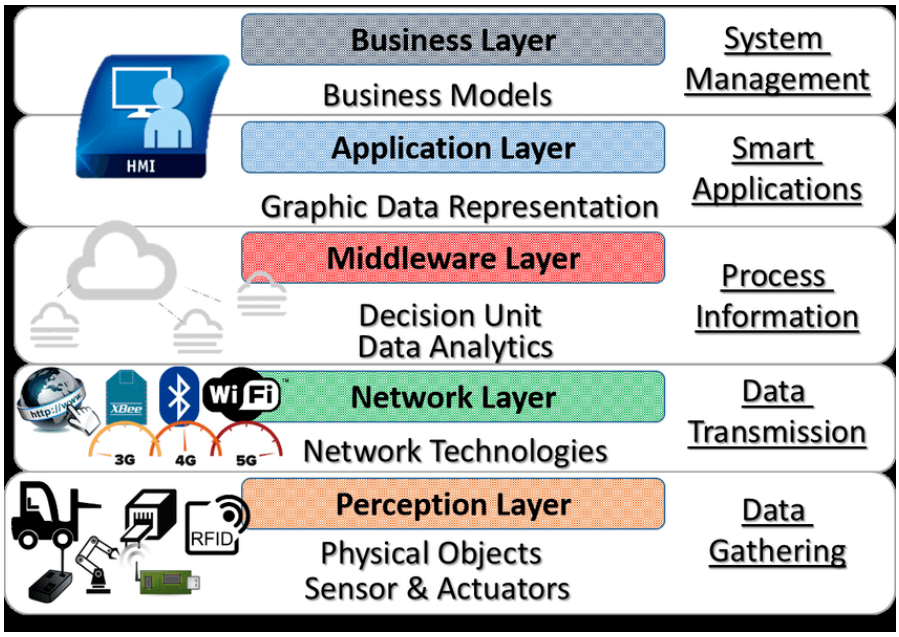


Figure 9 5 layer architecture of IIOT

7.2.1.4.2 The Benefits of IR 4.0

The application of IR4.0 concepts were largely seen it improved the asset efficiency, identification of bottlenecks, process improvement, reduction of wastage and going green.

Based on a study released by Forbes it impacted the downtimes by 35-40%

Improved the manufacturing process by 15-20%

Quality improved by 35-40%

Efficient asses production increased up to 35-40%

In a wholistic point of view, productivity experienced a spike of 65-70% (Damani, 2020)

In summary by the help of IR 4.0, it put forward the concept of a Smart factory that utilizes technology and business for enhanced functional operations.

7.2.1.5 Smart Factories

The smart factory, one of the most essential part of Industry 4.0, is made ‘smart’ in the sense by efficient communication and connected operations. It has decision making from the shop-floor to the providing upper-insights to the supply chain. It is a smart factory of ‘things’ that are integrated with IoT, Sensors, RFID, robotics. (Matthew N. O. Sadiku1, 2021)

The basic structure of a Smart factory can be defined in 3 terms:

Figure 10 Structure of a smart factory.

- Data Acquisition is done by the use of data collecting devices like sensors, IIoT gathers the data from connected machines in the system and utilized data management tools, they are the main source of insights and first step in decision-making ease.
- Data Analysis is done by machine learning techniques to create sense in the accumulated data. Things to work on are predictive maintenance, efficiency increase in the workflows and other optimizations of the sort.
- Intelligent Factory-Automation is the final process, where the machines are communicated the instructed steps. These machines can be on premises of the company or can be present somewhere outside for e.g., relating to supply chain processes.

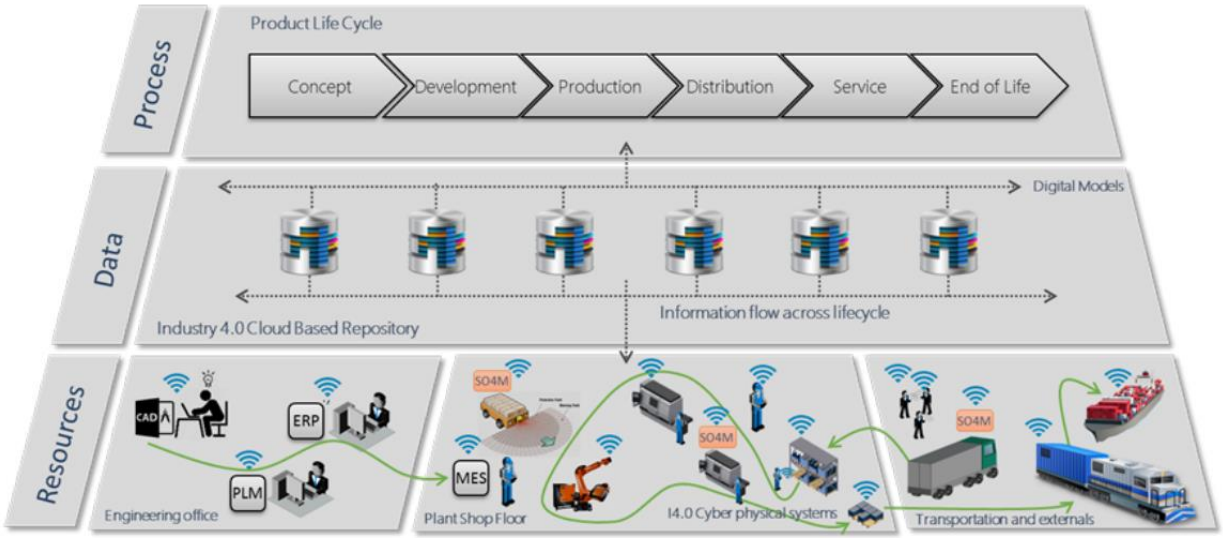


Figure 11 Overview of a Smart factory

The MOM or better known as Management of Manufacturing Operations are the actions of a production facility that tracks optimize and sustains the plant in focus with production, quality, material management etc. as per IEC 62264-3 which is International Electrotechnical Commission.

In addition Virtualization also occurs in the smart factory so a digital copy of the product throughout lifecycle is tracked as well. (B. Ghaouar, 2013)

M2M (Machine to Machine) information flows are developed and H2M (Human to Machine) settings are also defined in an efficient manner for the tasks that cannot be fully automated.

Since softwares are utilized in every process in the smart factory there are fine lines that divide and define the roles of each IT product and the reasons of their deployment.

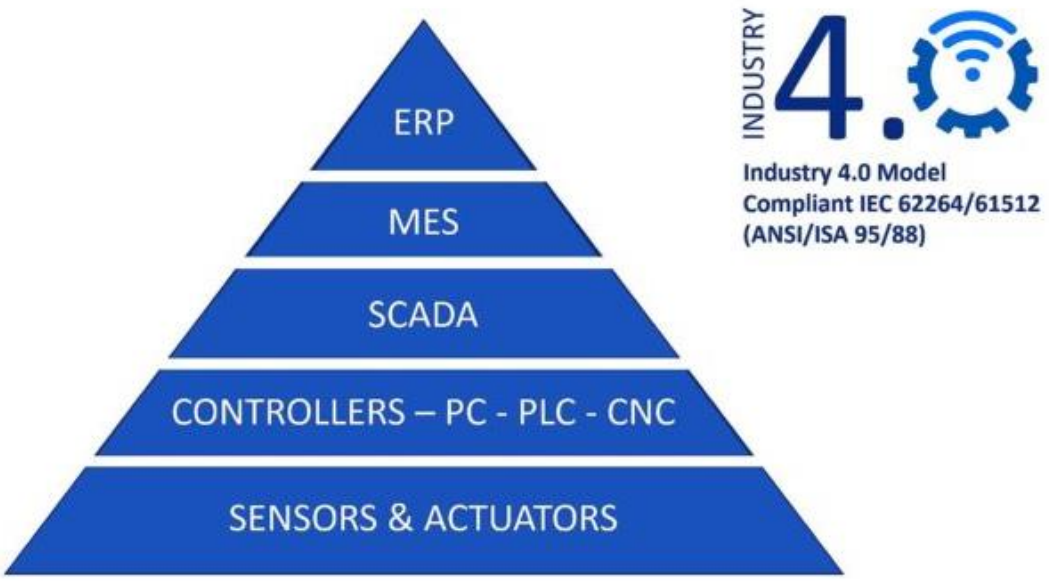


Figure 12 The automation pyramid source: C-Tech

ERPs are utilized and deployed at the business level of the organization that supports the planning, supply chain management SCM, HRM human resources management and Accounts. One of the world renowned ERP system is SAP but various other ERPs are available in the market that are customized according to the factories as well.

MES Manufacturing Execution System is the tool for MOM as explained earlier, and it helps in the production and reports that are managed with it, operations of repair and maintenance, keeping a look at the workforce and resource allocation. Etc.

The supervisory level of automation better known as SCADA is the abbreviation of 'Supervisory Control and Data Acquisition', it is a high-level supervision of machinery through graphical user interface.

The level of Controls is the hands-on control at the device level, with the help of equipment like PLCS that are programmed logic controlling, which is followed by the last level which is Sensors and Actuators that are literally the machine level control.

7.3 How PLMs Complements Industry 4.0 - Positions itself in Automation Pyramid

The PLMs lies in the ERP section i.e. the business section of the pyramid and strongly integrates with the platform for product development phase. However it has strong relations to the MES as well.

A visualized and simplified explanation is given below for the relation of ERP PLM and MES is shown below.

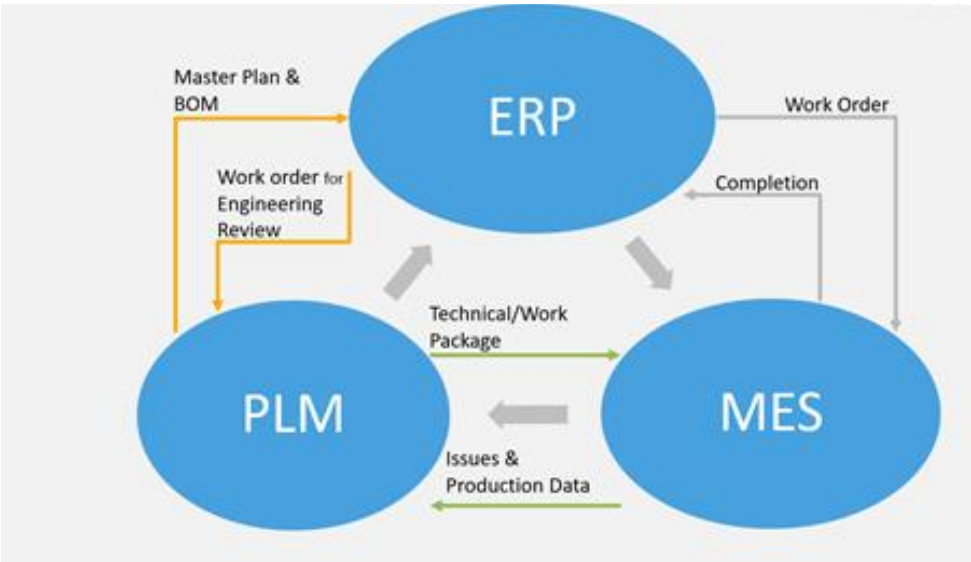


Figure 13 Relation of ERP, PLM and MES

Utilizing PLM with MES and ERP amplifies the Lifecycle Management of Products. The data of Bill of Processes BoFP adjustments is very crucial for the MES when feedback is given to the engineering it greatly improves the knowledge base for the future.

Engineering Change Order Management ECOS when they are born in production floor level goes to the MES and if PLM is integrated they will be a part of build-history for the product. This greatly ramps up the product development phase for the next products.

The downstream PLM – MES relation:

- As designed & As planned data provided by PLMs
- Product designs, Process Plans for the production initiation.
- 3D simulations and MBOM as developed for the product in PLM.
- Work Instructions to the shop floor
- Routes, Operations, dependencies, parameters that are set for the production.
- Information regarding Shop floor saved in the product bank for specific article.

The upstream /close loop MES – PLM relation:

- As built data feedback reverted to PLM.
- Production Information data and record
- Product and Process Information
- Quality reports
- Updated work-instructions.
- Generic issues that arose and how were they tackled.
- Nonconformities reports

The PLM to ERP relation is:

- Sending the EBOM, MBOM
- Process planning
- Manufacturing Planning

The ERP to PLM information reverted is:

- Work Orders
- Quality Requirements and Specifications
- Skill and Precision Level

The Business Process Integration BPI and Management BPM are concepts that are used to integrate the data related to the product gathered across the processes. In the whole lifecycle we identify 7 main processes of business as:

- Need
- Preliminary designing
- Developing
- Producing
- Usage
- Maintaining
- Recycling/Dispose (Anis Ben Khedher, 2012)

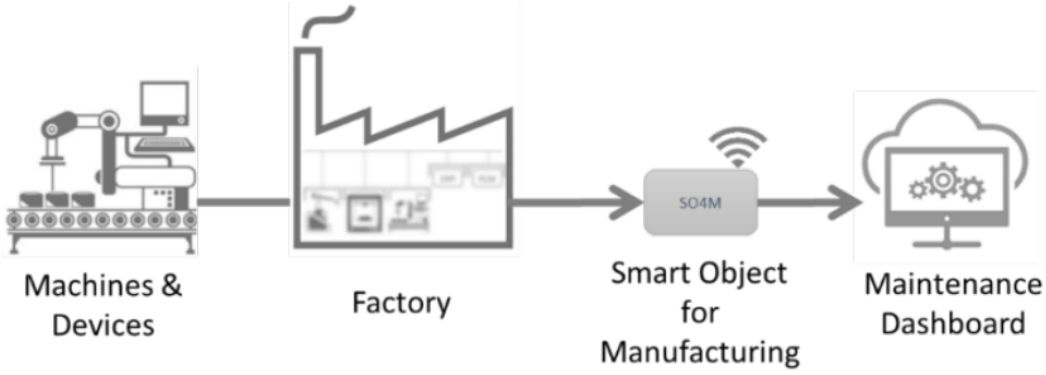
PLM integrated alongside with ERP and MES in the Industry 4.0 pyramid in a smart factory will provide useful business integration in all levels of lifecycle.

7.3.1 Concept of Maintenance as a Service

The Reference Architectural Model for industry 4.0 (RAMI 4.0) gave an idea of I4.0 components. It modelled the cyber and physical system that is machinery and parts in real life environment that are linked virtually with real-time communications. On of the key necessity of I4.0 is data collection and analysis to add value. This stored data and method of inter-communication is accumulated to what we call Administrative Shell. (L, 2015)

Managing Maintenance is a severe problem for today's business, we cannot afford to have delays downtime of productions as they significantly affect the cost and from the point of view of Environment health and safety EHS. The data based analytical approach to maintenance activities is improving the smart factories by the help of the technological pyramid of ICT. I4.0 moves the norms from corrective to planning of maintenance and finally to predictive and then to self-fixing maintenance that minimizes the human resource.

Modern models of maintenance contracts will give rise to 3rd party maintenance services as well where they guarantee the uptime of machinery with a service fee and fix a machine also remotely or with the equipment of self-fixing. Greatly affecting the total ownership costs.



The figure below showcases a case of where PLM and ERPs are utilized in a maintenance as a service model by the help of cloud-based maintenance managing systems, alerting the smart factory where an employee sitting (be it remotely) can also help resolving. All thanks to the updating of knowledge bases of PLM and ERPs.

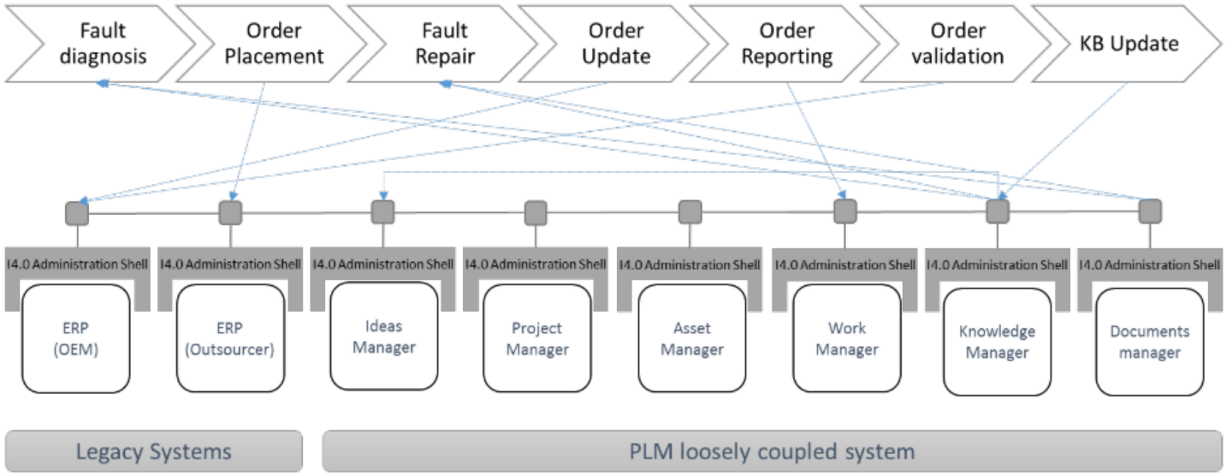


Figure 14 The modules of system assisting the maintenance activities.

7.4 The main players of a PLM:

Understanding the breadth of PLM software from a holistic point of view is crucial for realizing the fundamental notions of PLM. So below visualizations is a conceptual PLM framework that cover all the pertinent components of a product lifecycle.

(Ezgi Venghaus, 2018) defined and extended the framework for better understanding PLMs with the help of two model inputs which were:

- *MTO Approach:*
  Prepared by Strohm and O.Ulich , MTO stands for Men, Technique and Organisation. It concluded that for the successful implementation of computer aided systems relies on considering the technique, the organization and sturcture, the worker along with its comprehension/qualification. (Oliver Strohm, 1997).
- *The EOS approach*:
  EOS stands for Engineering Operation System. The approach was prepared by Fraunhofer-IPK and TU-berlin universities for giving a macroscopic view of manufacturing, production and related surroundings of developement. EOS primarily focused on interrelations of 4 areas and stated that it is important for every engineering setting and can be exploited for the best use of PLMs. They were
  - Processes and Companies
  - Activities (engineering) of that company
  - The info and database
  - Software,tools and IT applications used. (Lünnemann, 2017)

Combining the two theories the conceptional PLM base framework can be visualized as:

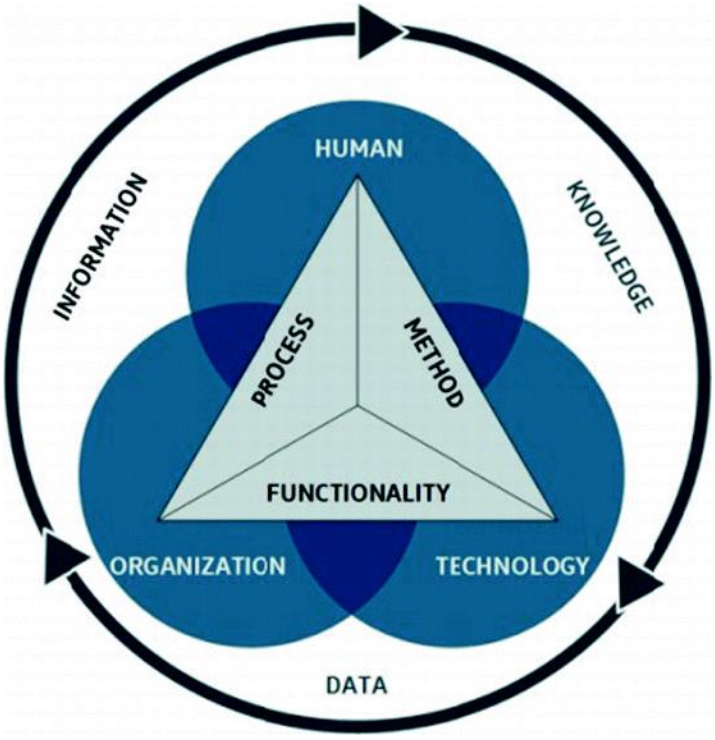


Figure 15 PLM's conceptional framework

The further explanation of the components of framework are given as:

7.4.1 Organization

The organization is seen by several research as a crucial element of PLM. Nevertheless, the meaning of the organization in the surroundings of PLM is not described in full. Organization includes both organization of structure and operation-execution. In order to properly implement PLM, it is crucial to take into account factors like the size of the organization, nature, and value as well as its degree of operations (such as worldwide). All managerial tasks, including decision-making, goal-setting, and establishing the strategy and vision, are included along side the management functions of organization which can be related to handling compliances, governing, executing analysis and summarizing reports and calculating economical values etc. (Stark, 2018)

7.4.2 Human

The term human in subject of PLM context is stated in the researches from the point of view of resource, having significance of skillset with its important components, alongside the activities of engineering. (Lünnemann, 2017) Further than these factors taken into account is the idea of the info-ergonomic approach and the function of work-psychology in PLM.

7.4.3 Technology

The information and communication technology or abbreviated as ICT is frequently evaluated as a way to specifically explain PLM. Here it is referred to define the PLM system as a single system of software. The term coined as PLM Solution if what can be called to something that supports the running of whole infrastructure of PLM software. Here the term Technology in this conceptional framework diagram for this purpose.

7.4.4 Process

During the analysis of PLM components the process is commonly taken into consideration as an element of the organization inside the domain of main business activities. In complement alongside the product lifecycle process, in PLM systems a process-oriented emphasis also exist.

In this conceptional framework, the process is defined as an specification of company and further as a network with flexibility and agility, created by the humans to complete their activities in the product lifecycle. Hence visualized in the framework with the bundle of humans and organizations.

7.4.5 Method

Method is stated as a specific set of steps for achieving or to approach anything as defined in literal terms. In background of PLM, A procedure like this is generally stated as a part for PLM solutions that vary company to company and synonymously utilized in place for tool, technique etc. that help in managing of info across the lifecycle of product. In the conceptional framework, as visualized, method is charactered as a procedure to execute activity/tasks by humans using technology. (Ezgi Venghaus, 2018)

7.4.6 Functionality

Functionalities are described in the context of PLM to characterize the capabilities of PLM. Going beyond it we take functionality as a structure of technology that assists to map the process chalked out by organization. Hence in the framework, PLM functionality is visualized with technology and organization.

7.4.7 Data/Knowledge/Information

The central idea of PLM rotates around all the aspects of managing knowledge, as PLM assists in obtaining, organizing and reutilizing of knowledge throughout the product life-cycle. While information is stated as organized data that is used to showcase in specific setting or environment. Knowledge on furthermore can instill visions, insights, conclusions, judgmental statements, true/false, knowhow in the boundaries of human-factor. (Farhad Ameri, 2005)

7.5 PLM & Knowledge Management

As the trend of moved from the era of industries to the age of information, the most significant thing to provide competitive edge became Knowledge. The terms data, information and knowledge many times used in interchangeable manner but are different things. As explained before data is not present in an organized way. Information can be considered as an aggregate of data which can be used to make decisions, further moving on to knowledge it becomes insightful and helpful in solving problems. (Minnesota, s.d.)

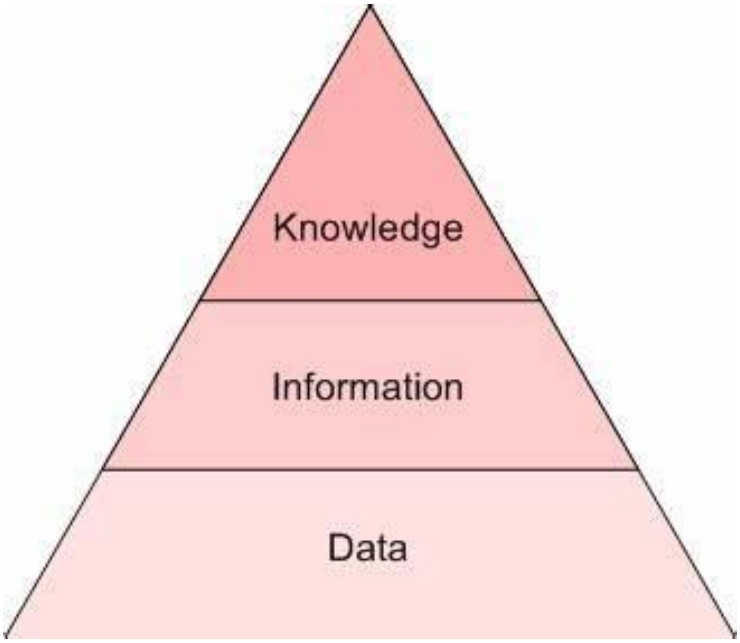


Figure 16 Data vs Information vs Knowledge

7.5.1 Knowledge Base

Extending the definition of knowledge to lifecycle knowledge which can be defined as knowledge accumulated through variety of process across the lifecycle of product. Connected to the lifecycle at every point is a human or non-human agent that communicate with the base knowledge of PLMs. The knowledge base of PLM is not exactly always a physical knowledge base. On the other hand it is an framework interconnection of knowledge which is spread across different repositories which are then united digitally using technology.

The PLM users interact with the K.B of PLM as any other knowledge base, in 2 prominent ways which are ask and tell. Its either they are increasing new portions of knowledge to the system, this is called TELL, or they are retrieving information through queries from the knowledge base of PLM, which is referred to as ASK. (Farhad Ameri, 2005)

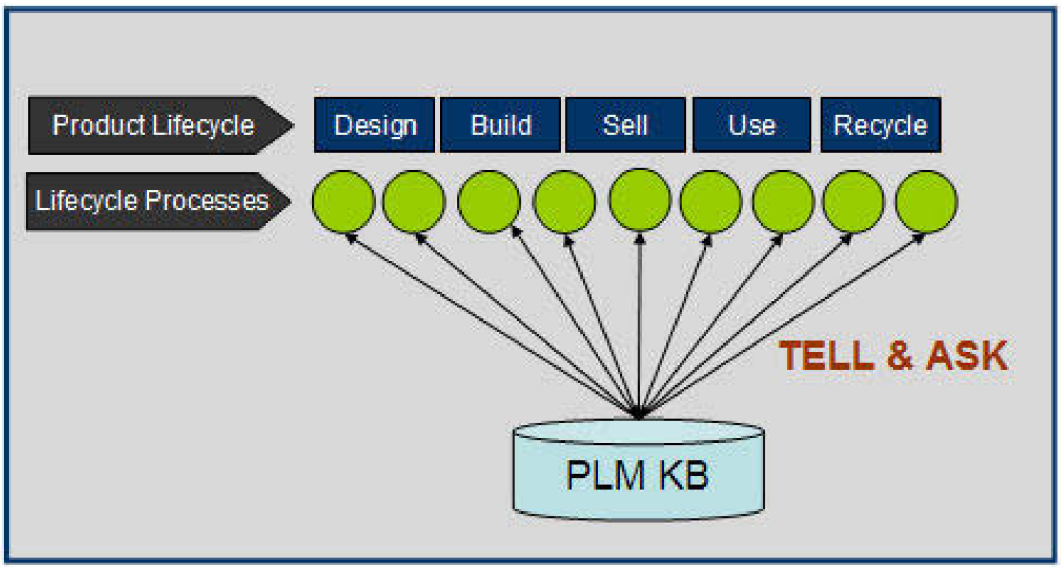


Figure 17 ASK and TELL model of PLM knowledge base

Figure above shows a simple model of ask and tell working in a framework of PLM. The amount, nature and broadness of data, info and knowledge will vary if we maneuver across the different stages of lifecycle. As an example the designing process are considered to be more heavily relying on the knowledge as compared to process related to selling and supplying the product that only require some info like a report of previous sales. (Xin Guo, 2023)

Demonstrating with a practical example how the ask and tell model will be utilized in major stages of product lifecycle.

For example in the designing phase the designing team will have to select a material and they have concluded that a specific grade of steel can not be used as it does not complies fully with the mechanical specifications of a product X. If this information is stored in the correct manner can be helpful in the next time for design team when they have to come up with a product that is like product X. The check list of a organization for engineering purpose is a good reference to this knowledge, these check sheets have improved overtime and have become knowledge for their scope. Example if an automotive dies manufacturer has such knowledge of variety of body parts of a vehicle that consist of guidelines related to their production. It can be consulted for the feasibility and conformance of designing (ask) and contemporarily can be used to feed the system more knowledge for improving it (tell). There are various cases like this of ask and tell that will keep going through out the product lifecycle and will help improve the knowledge base. Making the processes leaner and improved. (Farhad Ameri, 2005)

Phases of product lifecycle	**Processes of product lifecycle**	**Tell type interaction with a K.B of PLM**	**Ask type interaction with a K.B of PLM**
Designing	Selecting the material	Steel is not considered a viable product	In a product of same nature which materials have been used in past?
Building	Q.C process (controlling quality)	An equipment is not good for some specific precisions	What is normal scrapping speed for a drill for a specific steel part?
Building	Selecting Vendors	A specific supplier's delivery time is X times longer than what is planned	Does supplier A is technologically capable enough to produce a specific product
Supply Chain	Shipments	Delivery of a product in method X caused problems in the product as reported	What are the shipping conditions for a specific product?
Services	Modifying Oils	Vehicle X needs to be changing oil after every ABC mileage	What is a specified mileage for oil change for X vehicle ?
Disposal	Dis-assembling	Due to engineering reasons the successful disassembly of a specific part is not feasible	How much aluminum is used in the product X?

An in-depth knowledge base of a PLM can significantly improve the efficiency of process that heavily rely on knowledge. Hence improving the cash-flows and consequently improving the competitive position.

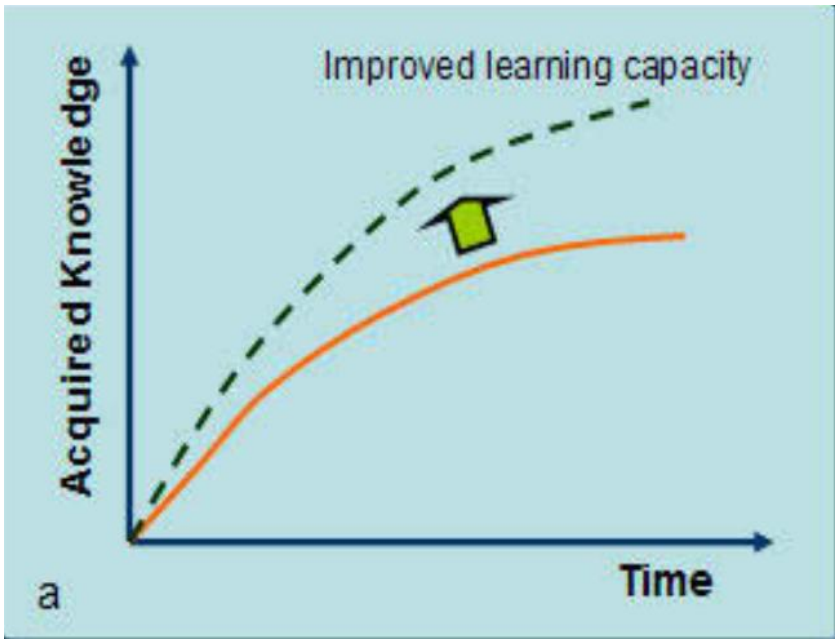


Figure 18 knowledge vs time for improved learning capacity Source: Product Lifecycle Management: Closing the Knowledge Loops

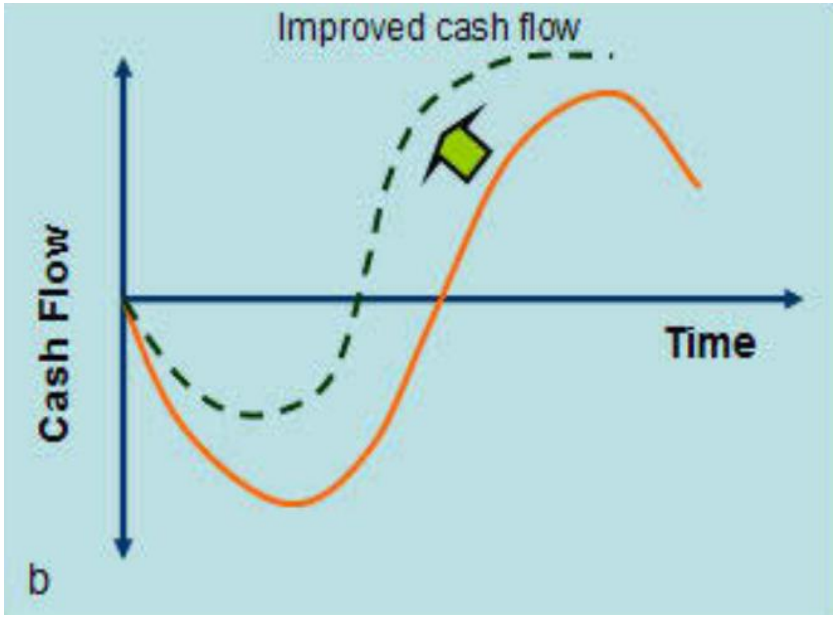


Figure 19 cash flow vs time, Source: Product Lifecycle Management: Closing the Knowledge Loops

7.6 Choosing the Ideal System – Key Requirements

The organization must be laser focused with their needs when considering choosing a new system. Obviously, the company has already gone through the initial assessment of why they require a PLM system they have identified the bottlenecks that are stopping them from achieving the set goals. When selecting the ideal PLM system, organization needs to define the key requirements and set of solid features that needs to be catered.

7.6.1 Bill of Materials (BOM)

Having a shared source of knowledge inside your organization is crucial when developing new products. A BOM is essential to include on your list of key requirements because of this. Because at least the desired system should offer an exact definition of a certain product and its components. Features for diverse team members, including designers, engineers, and various related employees who often share same projects, are included in more sophisticated alternatives. One may also discover systems that give enhanced BOM display choices so you can immediately examine the details of the materials and related information.

Even better systems offer a more thorough Bill of material managing. Some systems enable designers to access multiple level product's trees in a single location by extending a central-BOM. Furthermore, Users may observe every stage of assemblies and parts thanks to 'drill down' capability. In some advanced options, the tools for risk assessing and health assessments access data online on the components you employ across the course of a product's existence. Users may also obtain compliance related info and see component's availability. Finally, you may get alerts if a BOM is changed. (Hayes, 2022)

7.6.2 CAD Extensions and Integration Management

Engineering & designing processes can be brought in line by CAD features, which are occasionally offered as a separate software product. In PLM, CAD tasks and file management and is a huge benefit. When product configurations change throughout the course of its lifespan, your chosen software should be able to handle those changes while keeping the product's functionality and physical characteristics. Your processes should undergo widespread modifications in production engineering, and the resulting Bill Of materials and plans should reflect these changes.

Moreover, ideal system has to consolidate files management so that all the team will be accessing a single repository of information. Several systems include documentation tools, documenting in a mobile manner, analysis of product lifecycle, and collaborating options etc. The majority of systems also have automatic recording of product's history. Several PLM systems allow tracking of CAD related data and support Bill of material's import.

7.6.3 Product Data Management

With the right PDM module, we can exploit designs of products, requirements, and procedures in a single source. Stakeholders, design team, and other fellow members of the organization can revolve data and upload notes, info that further enhances collaboration. A good module will help promote data sharing, easily review the supplier data, material information, CADs & BOMs, lifecycle data. But the question that needs to be asked is if PDM is alone solving the problems or a PLM is required to fulfill the needs. PDM serves as one of the inputs for the giant framework of PLMs, some major differences are mentioned for further clarifications.

7.6.3.1 PDM vs PLM Major Differences

Phase	PDM	PLM
Design	It only saves only data of designs, cannot act as a design tool. Tracking project status, or link to external (non-design) data.	Design data is created in such programs that have integration with PLM so that all version/revisions and latest releases are tracked real time. (Mika Lohtander, 2014)
Prototyping	Prototypes usually don't have any data in the PDM. They are produced based on if-needed. Basically, they are not assigned a lifecycle stature.	In PLM the designer assigns a a prototype label/status to project. All the data is accessible with the design documentation when required to manufacture. (Nafisa Osman, 2018)
Volume Production	PDM may store the manufacturing files, but the info regarding the sourcing and inventories is not present there.	Users of CAM/CAD can assign a status of in-manufacturing to the item, and users start attaching the sourcing or inventories data, also maybe other data of ERP can be added in the project.
Revisions	It may track revisions within a project, or they must be tracked under specific project/part number. It only tracks revisions to design data.	In PLM systems, change in orders and Revisions are assignable to every phase of project data, which includes assembly data, source code of applications and the primary technical data of product. (Mogo, 2009)
Lifecycle Tracking	Not generally but some PDM may assist in visibility of lifecycle status, even then it can be only applied to certain objects.	It tracks lifecycle status in every aspect of the design, from individual parts to product documentation and the whole assembly. (Merja Huhtala, 2012)

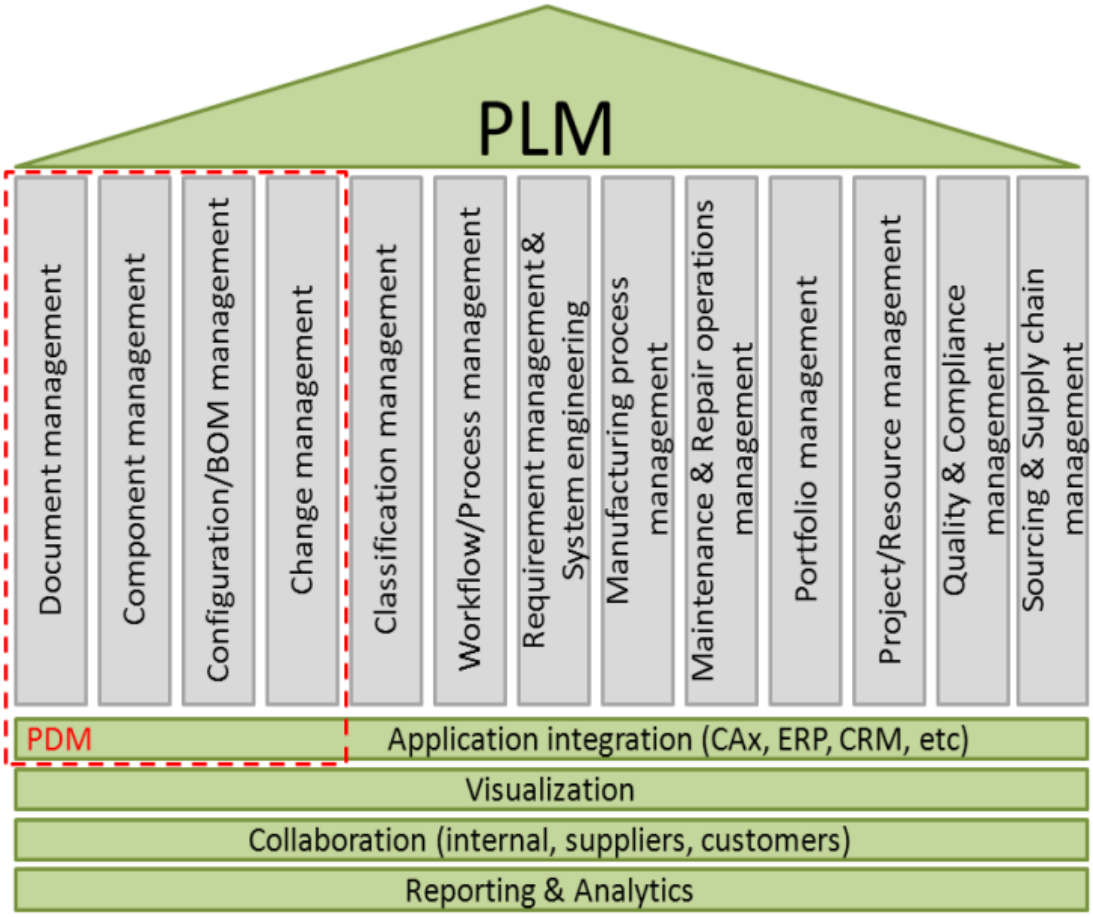


Figure 20 Holistic view PLM vs PDM

7.6.4 Compliance and Governance of Product

Ensuring that the process or product (be it physical or software) of organization adheres to regulations such as standards, laws, guidelines is known as Regulatory compliance (Michael Felderer, 2020). These address the goals and objectives, while mitigate risks. In the modern industry there are compliance standards associated with every step of the lifecycle. Since the data for auditing purpose will be extracted from the gathered knowledge base, it is a necessary requirement to be compliant.

A compliant PLM can always add value by decreasing time to market (TTM), improving product portfolio, smooth transition from R&D to Manufacturing. (Gosaas, 2022)

Some major product related standards are:

- ISO
- REACH
- FDA Regulations
- SEC Guidelines

Another point to be kept in mind is also the PLM data handling rules followed form the vendors point of view that ensure security and avoid unwanted interruptions like:

Repository rules, real time monitoring, and other rules for assuring guidelines like Security Technical Implementation Guide (STIG). (Oracle, 2022)

7.6.5 Project Management

An ideal PLM should be configured with the tools required to manage regular and turnkey projects effectively. Since PLM has the knowledge base, it needs to be utilized for sound decision making. Decision making is crucial at every step of the lifecycle, project management is utilized for sound decision making. But sometimes conventional and manual project management cannot give desired outcomes. In PLMs there are levels to decision making because it all falls down to the area of start of problem, it can be operational problem, a problem of middle-management or a completely strategic one. (Sumit Malabagi, 2020)

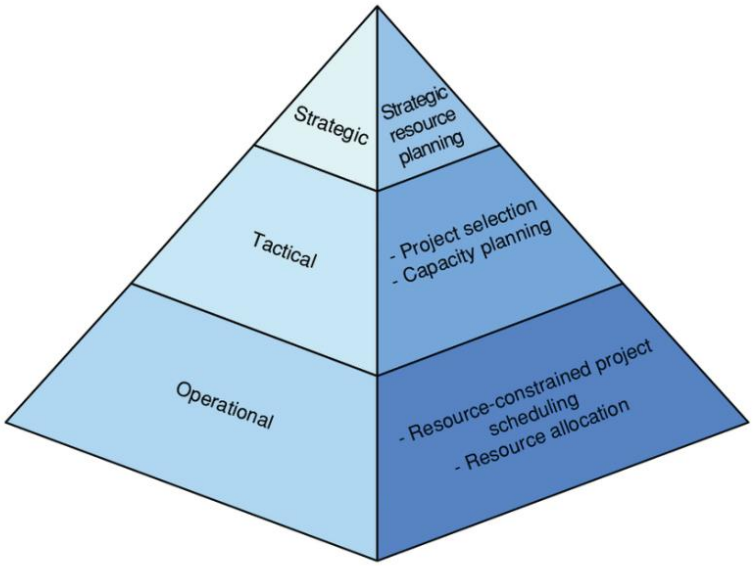


Figure 21 Decision's hierarchy levels in Project Management by PLMs

7.6.6 Quote Process Management

The quoting process can be extremely wide since the data is being gathered from different sources and needs to be analyzed. This can be solved by a PLM solution that uses its knowledge base and coordinates and organizes it for the designing and other engineering teams. This ensures that the team spends less time on searching the data and more on the respective work. Some tools that help in this module are:

- Configure to Order (CTO)
- Engineering to Order (ETO)
- Automated creation of work order

7.6.7 Managing Risks

Through PLM the teams can do management and minimization of their risks with some specific modules. Risk reduction in initial stages avoids problems from escalating as the product moves from development to further stages greatly lowering the costs. Risk analysis, CAPA(Corrective and protective actions), real-time visibility of projects are tools from PLM solutions used for better visualization of pain-points. It is important to make sure that PLM is interconnected to crucial elements like specifications, supply chain, pricing and performance standards. (Hayes, 2022)

7.6.8 Hierarchy of User Access

One of the key requirements is that the system should be able to completely define access levels for different type of users from the information present in PLM. It should be equipped with user-access controlling after clearing the user can have access to a limited amount of data as defined. Options like grouping, creating permissions, role hierarchies should be available.

7.6.9 Work flows Management & Change Management

This option is a key requirement in almost every PLM to gain insight related to the activities of organization. Phases are to be outlined for projects, with the assignment of mile stones. (Sumit Malabagi, 2020)

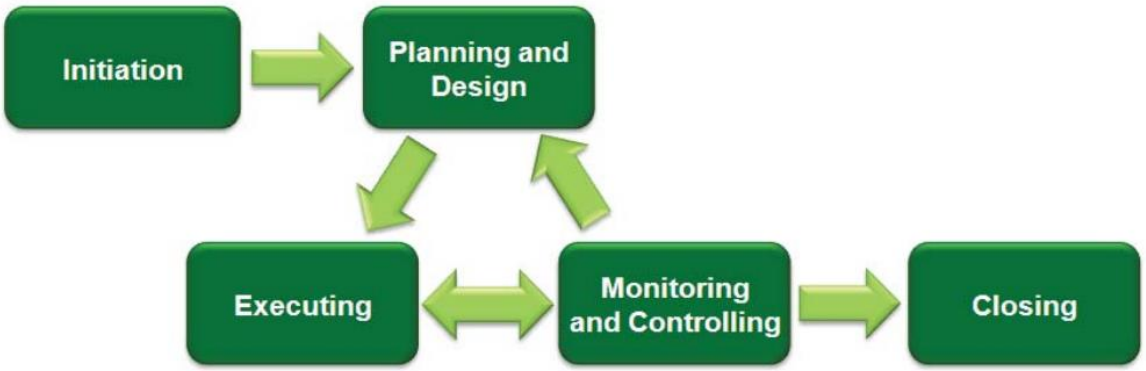


Figure 22 Sequential Faces of a Project

Key techniques that are to be considered for a PLM solution can be Change Management, Handling portfolios, management of processes and resources.

7.6.10 Deploying

Another key requirement to be considered is how the PLM system will be deployed in the facility.

- Cloud Based
- On Premises

The cloud based option is relatively simpler to install and updation is easy but the risk of downtiming is far greater in the cases of updates as they update more often.

The on premises hosting installation provides more control on the PLM but the system migration in decisions of update of moving to a different product can be a work-intensive process that will require specialized professionals. It depends on company to company. (Sihkha Singh, 2019)

To sum it up there are various key factors involved in deciding when to adopt a PLM system and which PLM system is more suited according to the organization. Summing up the adapting process with a flow chart for implementation process PLM systems. (Myung, 2015)

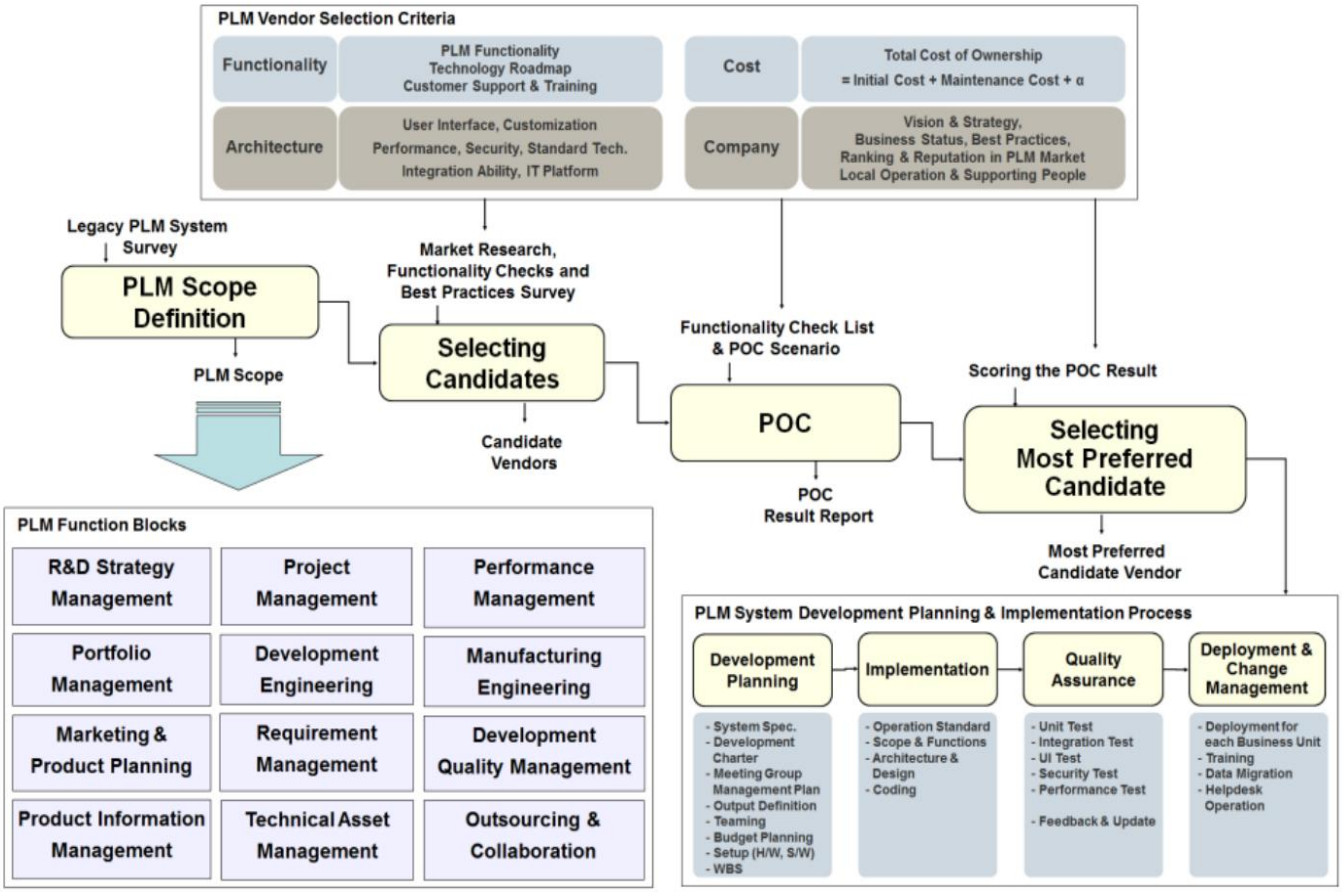


Figure 23 Flow chart for implementing the PLM system. Source: MDM in PLM for the Enterprise

7.7 Adapting to a PLM, dimensions of adaptation

The implementation of a PLM means altering the environment on enterprise level, since it manages all the lifecycle phases. (Ezgi Venghaus, 2018) defines the dimensions of adaptation from 3 different point of view.

7.7.1 Organizational Adaptation

Adapting the PLM from the organizational perspective is referred as Change Management. Here the main nature in change management is the company's condition it impacts the human resource and technological aspect by adjusting to the new process, methodologies and functions. It involves managing changes related to work culture, redesigning the business processes and involving PLM.

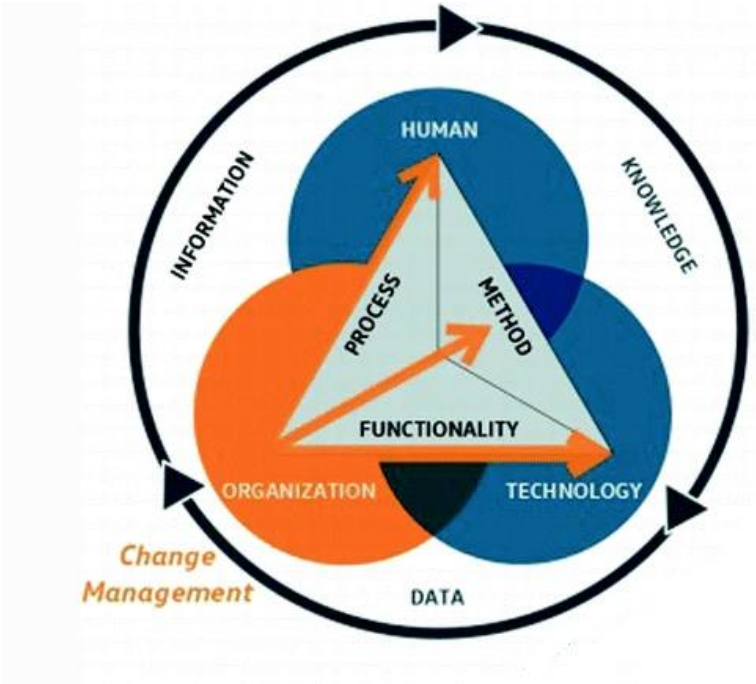


Figure 24 The Change management aspect of PLM adaptation

7.7.2 Human Adaptation

The Adoption dimension is referred specifically to the human adaptation of the PLM system and it involves factors related to the interaction of computers-employees and IT products based ergonomics, specific training and getting familiarity with the new implementation. This is one of the crucial factors that widens the aspects to PLM, how well the employees react to this broad change.

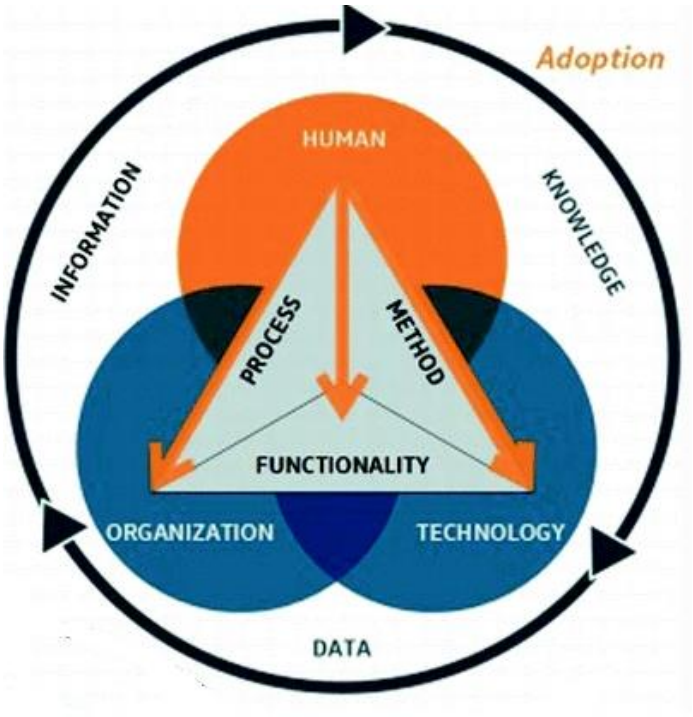


Figure 25 The Adoption aspect of PLM adaptation

7.7.3 Customization

The customization of PLM can be explained as the technological adapting of PLM it affects the entire view including the elements of human and organization in all three ways, processes, methodology and functionalities. Customization can be referred to the alterations made to the system according to the needs of business and for the ease of use for human.

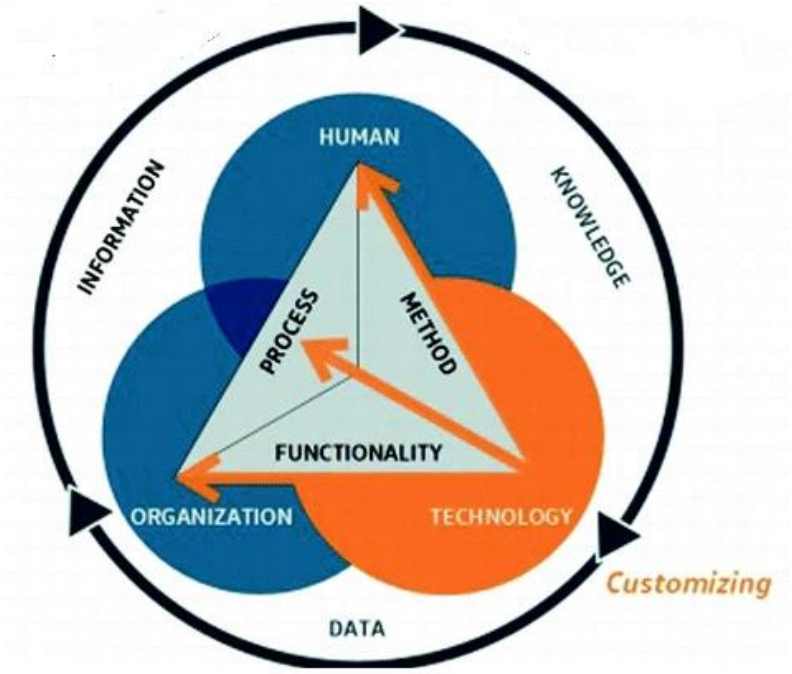


Figure 26 Customizing aspect of PLM adaptation

7.8 Commonly used PLM softwares

7.8.1 Teamcenter

Teamcenter is a product lifecycle management (PLM) system that is very flexible and up to date in terms of adaptability, making the user-process connection with the digital thread for innovation. Teamcenter core strengths are CAD management, PIM (Product Information Management) and handling the Product metadata.

Since the PLM system is also developed by Siemens itself, it provides strong integration with some of the most used CAD/CAM software like NX previously known as Unigraphics and Solid Edge by Siemens. Apart from that Siemens also provide independent PLM components for product development which also serve as a plus point for their own Teamcenter PLM. For example (Kineo for highspeed collision detection, PLM XML for software development etc.)

Teamcenter is used mostly by Automotive sector and Aviation & Aerospace sector. Market sector that mostly utilize Teamcenter are Enterprise level (1000+ users) and Small Business (50 or fewer employees). The users mostly utilize it's on premises services rather than cloud. On average it takes very long duration, 7.7 months for Teamcenter to go live in a company. (G2, 2023)

7.8.2 Autodesk Fusion 360 Manage with Upchain

Autodesk is one of the most popular organization in providing CAD solutions, their PLM system Fusion 360 Manage with Upchain is a cloud based SaaS product used by mostly Mid-Market segment(50-1000 employees) and Small Business segment. The PLM system is used in majority in Automotive and Mechanical/Industrial Engineering sector.

Again the competitive advantage of this PLM is that the same company has also developed its CAD solutions utilized by numerous companies worldwide. The strong points of Autodesk Fusion 360 Manage with Upchain is CAD, Data Quality and Reporting. Autodesk has created subdivisions/versions in their PLM according to the need of the company as Enterprise level-with full capabilities, Professional version specialized for design engineers, Standard for the extended engineering departments and a Participant version that is for project stakeholders and data/document consumers. On average it takes only 4.2 months for a company to set up Autodesk Fusion 360 Manage with Upchain. (G2, 2023)

7.8.3 PTC Windchill/Arena PLM

PTC is a market leader in the field of product development and innovation with a vast variety of software solutions. PTC has provided PLM systems that are developed according to the needs of users like Arena PLM which is 100% cloud based and PTC Windchill is installed on-premises of clients. PTC is providing assistance in product lifecycle management by its software not only to Enterprise level businesses but equally to Midmarket and Small Business as well. The major sectors taking advantage of PTC's PLM solutions are Automotive, Medical Devices and Electrical/Electronics.

One of the reasons for being an industry leader is their strong integration to design software like Creo which are also developed by PTC itself. Core strengths of PTC's PLM software are BOM Management, Version control and Engineering change order management. One of the drawbacks is that it takes around 8.1 months for a company to go live with PTC Windchill. Drawback of Arena PLM is that being 100% cloud based its CAD integration still needs betterment. (G2, 2023)

7.8.4 Oracle Product Lifecycle Management Cloud

Oracle Product Lifecycle Management Cloud and Oracle Agile are PLM solutions developed by Oracle. Mostly deployed by Electronics, telecommunication and Medical sector of Enterprise level. Oracle PLM solutions are highly praised for their Data Quality, Multi Level BOM options, Product approvals and communication options. On average it takes around 6.2 months for a

company to completely start using Oracle Product Lifecycle Management Cloud software. Mostly utilized on premises but there are cloud implementation options available as well. A majority of 3rd party consultancies are available for Oracle products improving its quality of support as well. (G2, 2023)

7.8.5 Aras

Aras PLM software is a niche product that focuses on being low code and easy configuration schemes. Aras is mostly utilized for product development by Information technology & services and Biotechnology sector, companies in majority are Enterprise level and others belonging to Mid-market segment. Aras is mostly utilized by companies on-premises in contrast to cloud service. Aras has a competitive edge of making things more user friendly by reducing the customization by coding and increasing the modifications by graphical interface. The strong areas of Aras are Ease in use, ease in administration and change management. (G2, 2023)

According to 2023 Report of G2, leaders of PLM market were visualized on a matrix as shown below

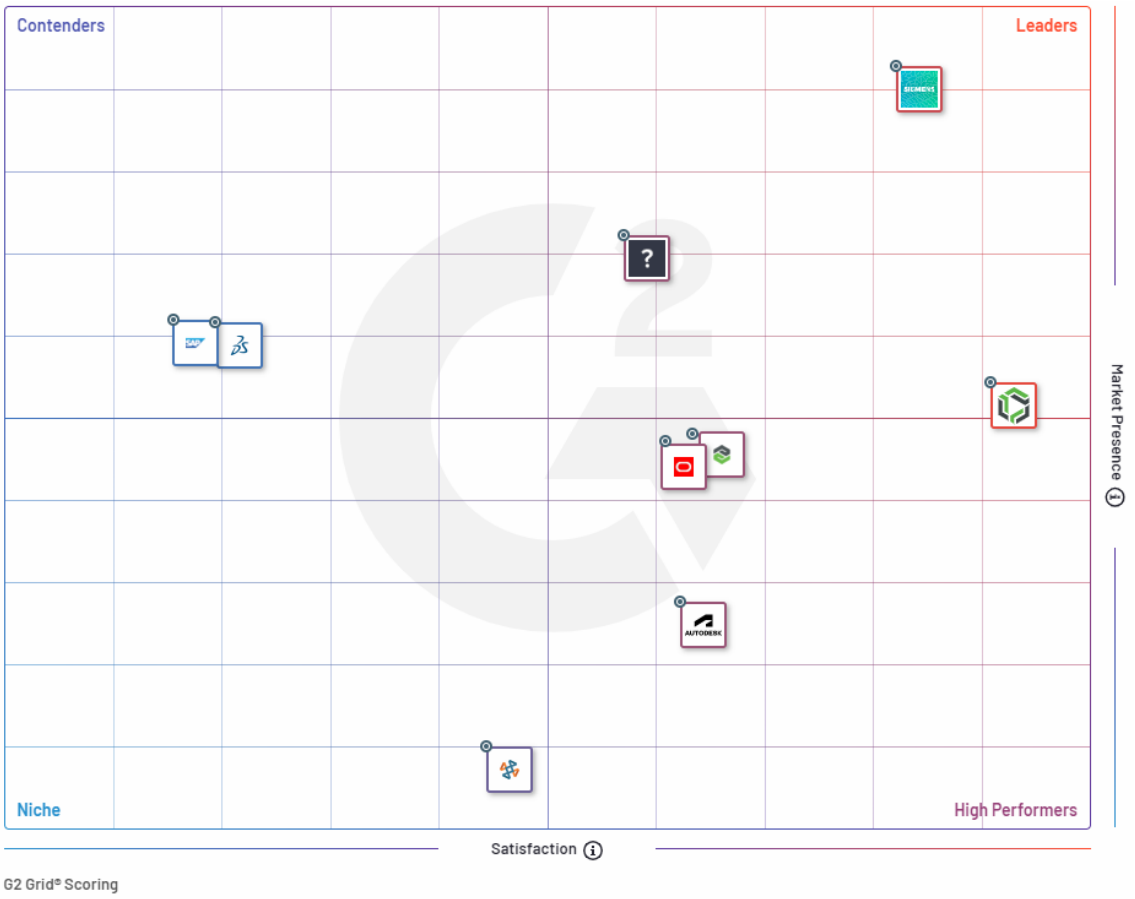


Figure 27 G2 Grid Report

8 PRO.FILE PLM System

8.1 PROCAD

Procad is a company that makes platform-based software products for the digitalizing the SMEs in the sector of Product Lifecycle Management and Document Managing. Having headquarters in Germany, Procad is in the business from 1985. The number of engineering companies that are utilizing products by Procad have increased to more than 700. Company has international business presence with offices and competence centers (that provide after sales supports and trainings) in Germany, Italy, Austria, Switzerland, Brazil, United States and Poland.

8.2 PRO.FILE

PRO.FILE assists you in the management, controlling, and integration of the product. It provides a single platform solution for information throughout departments, enabling the company to collaborate smoothly and consistently. Delivering an uninterrupted experience which permits business units to have hold on the updated and coherent data structure for all their respective purposes. The whole approach makes the process transparent and gives insight about the relationship of product data with auxiliaries like supporting emails, documents, and history while maintaining the compliance alongside.

PRO.FILE functions with the methodology of the 'product backbone' for unifying all the data and giving it structure that too in real time. The first question that comes in mind is how this collaboration is done across different locations.

8.3 The ETOR strategy for collaborating along different locations

Enterprise Transaction-Oriented Replication (ETOR) is a data replication strategy designed to improve the performance of a multi-site installation. Allowing organizations to work across locations that are dispersed but relying on the same platform information. As we know of today not only the big companies, but the SMEs are also manufacturing and producing items in locations that are global (Francesco Castagna, 2020), here scalability is important. ETOR provides a scalability by replication of developed data. The data is readily provided at the local level in all the places without the necessity of connection to a server which is central for reading/writing/editing or saving the data.

Practically a powerful database is permitting all locations to work from their personal data repository also making localized copies of all CAD models and other files.

The combination of file and database replication delivers an increase in software performance:

1. Access to document file data and database metadata occurs at faster LAN speed.
2. The number of database connections at the central office is reduced, as each site is equipped with its own database server to serve clients.
3. With the reduction of WAN data traffic, more bandwidth is available for other transfer tasks. File transfers between offices are generally faster as they are no longer burdened by intermitted metadata queries, speeding transmission.

8.3.1.1 REPLICATION TOPOLOGY

The strategy implemented by ETOR for database replication has basis on 'transactional replication' which has subscribers in queue with their updates. It means that the changes are bit by bit, they are incremental changes to the database of PROFILE which have to be replicated bi-directionally through the ETOR network.

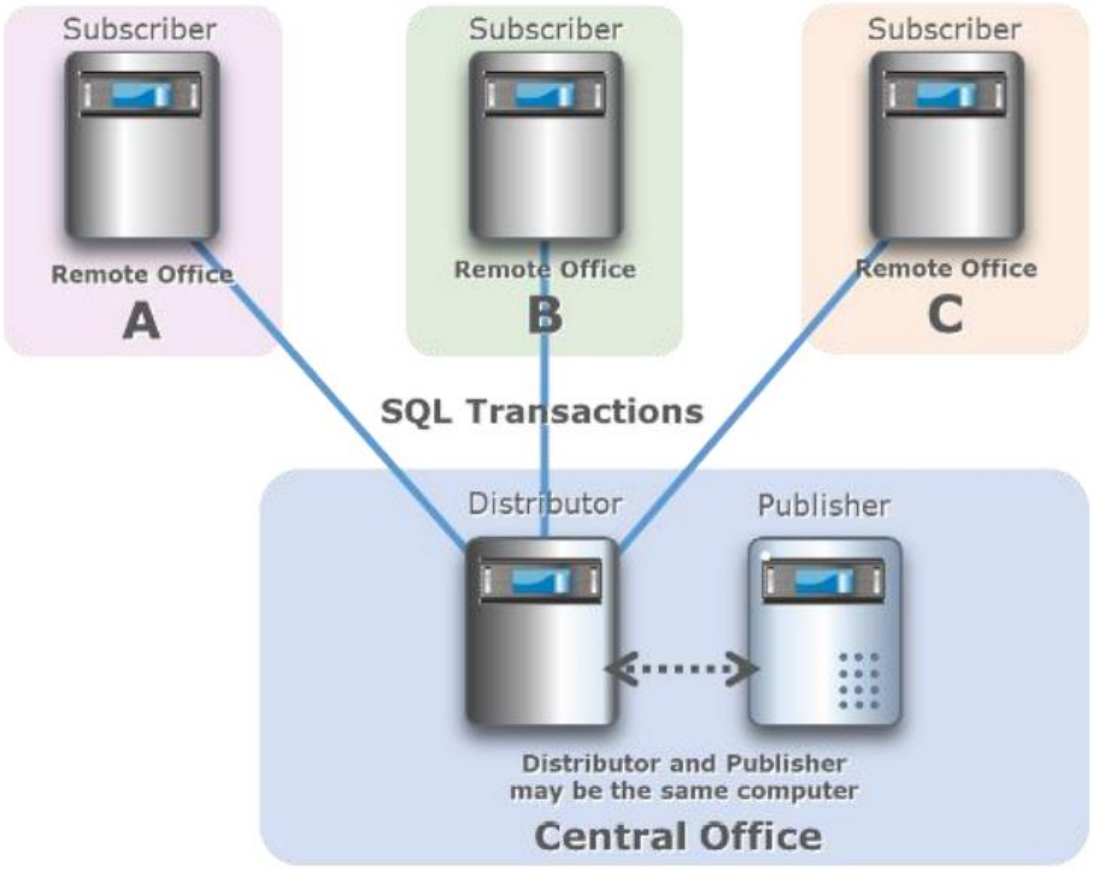


Figure 28 Replication Topology

The above topology represents a view of multiple server configuration to replicate a PRO.FILE database. 3 different roles act in the process: the Publisher, Distributor and Subscriber.

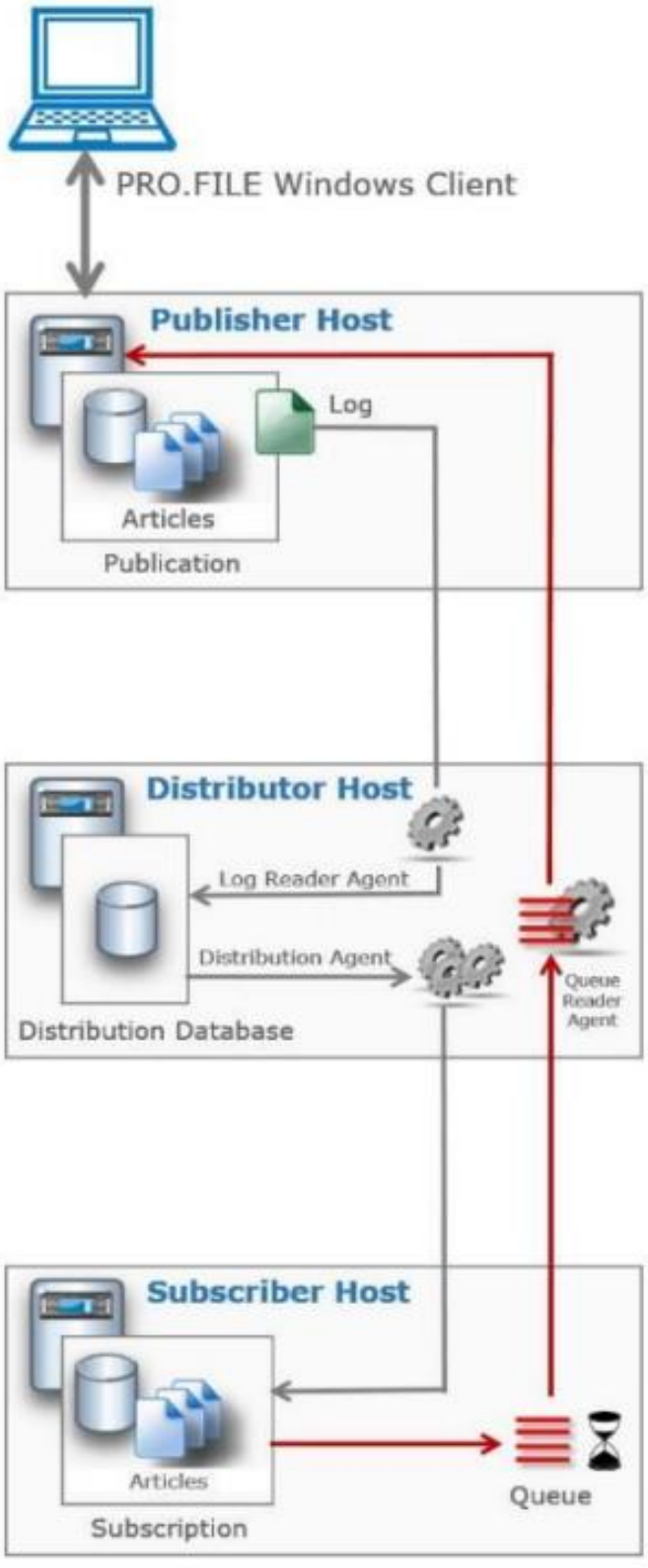


Figure 29 Flow of data between hosts and users

Publisher Host: This is database server for the central office. It is an MS-SQL server that acts like the PRO.FILE database's "master version". It publishes the 'articles' which are the objects of selected database (tables, views, stored procedures, etc.), all of which are then replicated by distributor host at each subscriber.

Distributor Host: It will coordinate the replication of all the modifications which are made to the already published articles (tables, views, stored procedures, etc.) across the system. Changes that are made at the publisher host are now 'distributed' to all the remote sites aka 'subscribers. Meanwhile it also handles the changes which are made by the subscribers to be done on the publisher. In an ETOR replication strategy usually it is a practice to keep the publisher and distributer hosts on the same computer.

Subscriber Host: This is the database server residing at the remote site. It is constantly receiving updates regarding the published articles from distributor host. And also sends the edits done by this remote site to database.

8.4 Part Management – Integrated Approach

In the modern manufacturing settings, the designing sector heavily depend on various type of CAD systems and the design team use software of different companies (M, 2018). This practice is sometimes also because of the client's request. For being able to handle this type of design system the data management of CAD should be integrable with these several MCAD & ECAD products.

Synching the meta data of product, BOMs and project information throughout departments of design and production can be challenging but we can solve it by PLMs. The workflow stoppage in manufacturing companies is usually because the data silos are different and the transferring of IT data from one system to another creates errors. This is time consuming and meanwhile BOMs are re-visioned, drawings become outdated or updated, the information regarding parts procured is not timely conveyed etc. (Denger, 2021). This leads to sometime going again to the production floor and reworking/remaking parts.

Synchronizing data in the PLM system

Since development team use CAD and store data in PLM and Production, Planning and Supply Chain staff use ERP systems for maintaining the data. PLM platform can be utilized in integrating these 2 platforms and smooth data transfer. PRO.FILE allows to integrate with more than 30 major CAD systems from mechanical, electrical, and electronic base, names such as NX, Solidworks, Solid edge, Creo, Inventor are all supported.

According to the g2 Report of 2023, SAP ranks as the biggest leader in ERP global market and in terms of market presence. PRO.FILE is a silver certified solutions partner of SAP. Apart from SAP, PRO.FILE is also a gold partner of Oracle, Microsoft and certified solutions partner for Autodesk, Solidworks and Siemens.

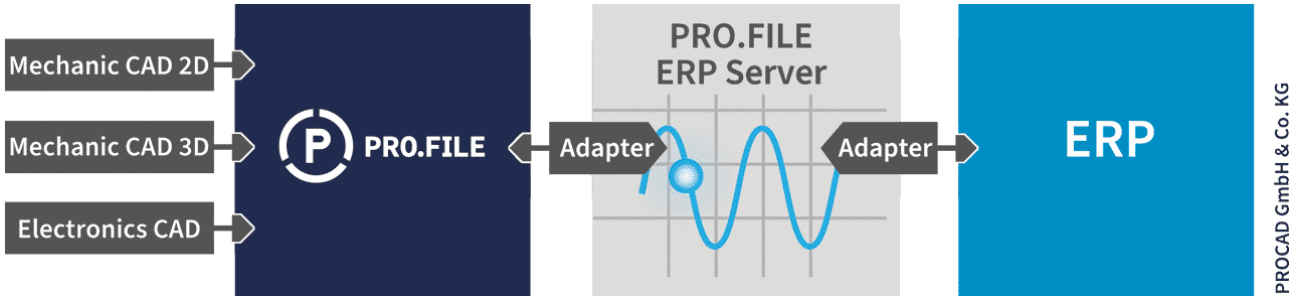


Figure 30 PRO.FILE Synchronization flow

This integration with multiple CAD systems enables companies to store product data consistently across all systems, a vital prerequisite for mechatronics today. It is imperative to focus on an integrated approach to product data storage. Today, it is no longer enough to manage mechanical CAD data in isolation. (Wynn, 2008)

Here PROFILE performs two important tasks:

- Aggregating information chunks from 'multi-CAD' settings like mechanical , electrical (e.g. line representations) and electronic CAD systems. PRO.FILE, for instance, in this case, now require only a simple interface connection with the ERP platform to transfer all the developed data into it.
- To put in sync, all master data developed in the designing phase to the ERP for planning, manufacturing, and technical procurement sectors. It involves more than only an exchange of info utilizing MS-Excel spreadsheet or ASCII files, that in another way is renouncing our hold on data. PROFILE require in this case a total control on process, transparency and an end to end method of documenting to monitor this whole data transaction.

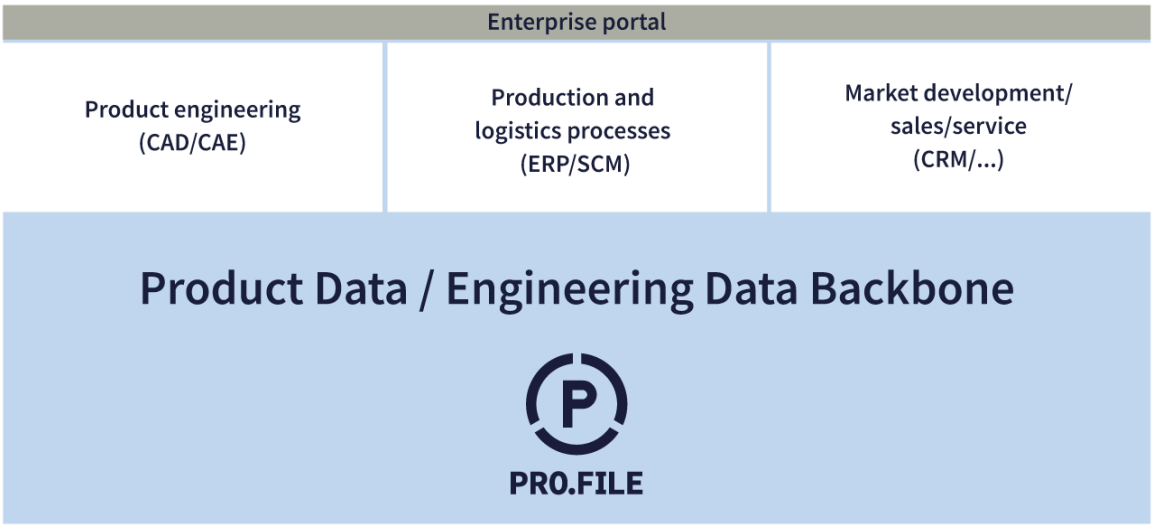


Figure 31 Holistic view of PRO.FILE structure

Parts only have of a "part description" in PRO.FILE. Part descriptions classify a design part or element. By the connection and structuring of parts, the bill of materials of an assembly is composed. The object "part" in PRO.FILE corresponds to an "article", "article master" or "material master" as often referred to in other systems.

The part structure is created in PRO.FILE providing all the necessary details related to the item. As shown below.

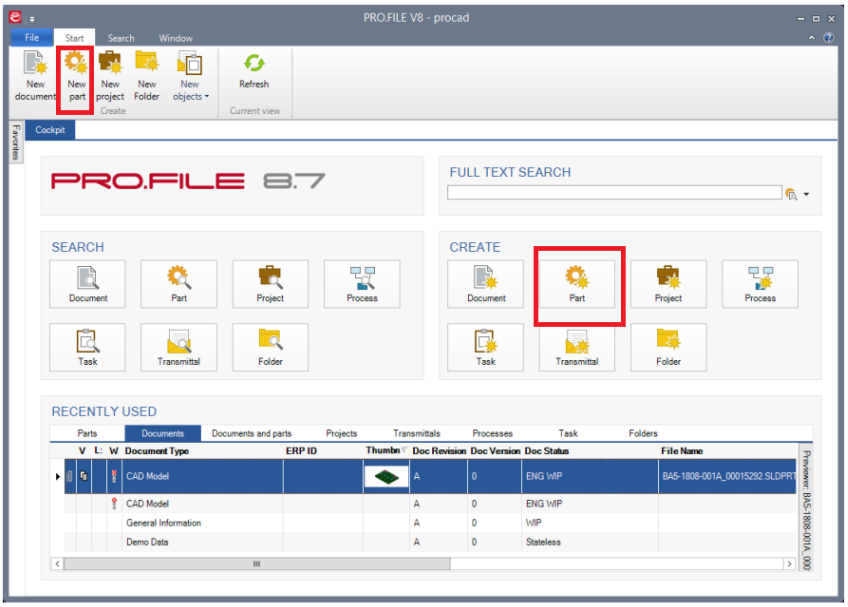


Figure 32 PROFILE home and part creation option

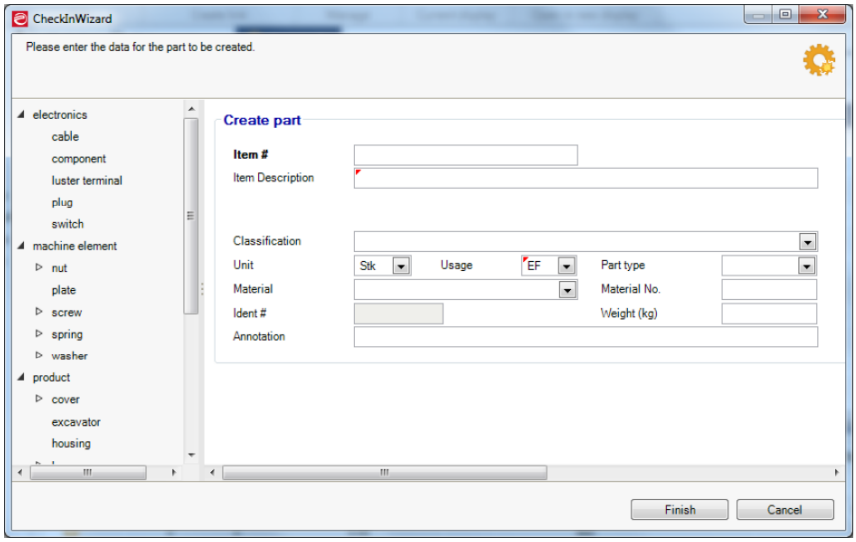


Figure 33 Creating a Part in PRO.FILE

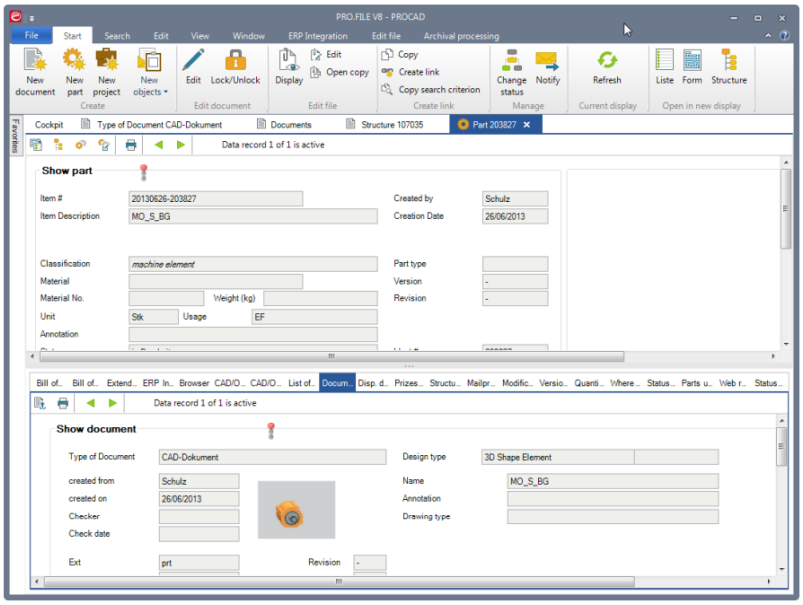


Figure 34 A created part/article

These created parts can be modified, deleted and duplicated from other parts in such a way that the complete Bill of Material structure is copied and linked in to the newly created part. Each part created contains its specific CAD files that are linked by the PRO.FILE integration plugin available for almost all major CAD softwares.

After the creation of Part the multi-level Bill of Materials can be managed and assemblies are created that contain multiple parts.

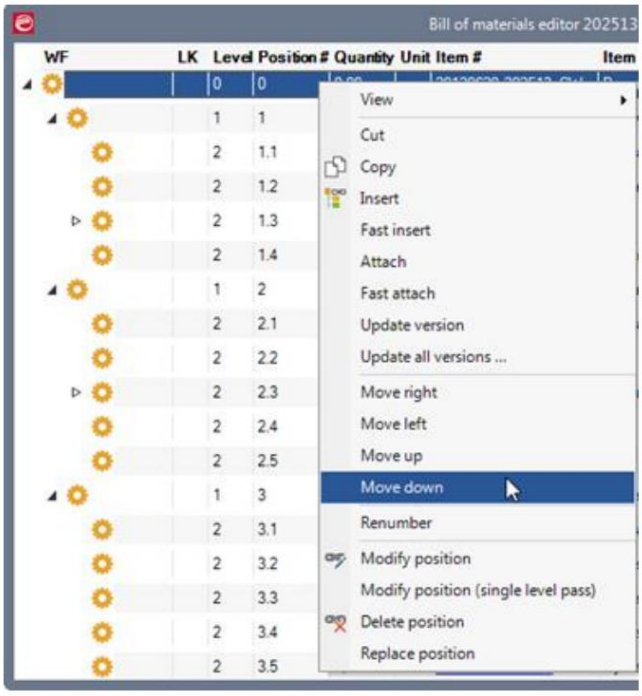


Figure 35 Multi level Bill of Materials management

After this brief idea of macro data management, we will now move to discuss the major elements of PROFILE namely DMS-tec, PROCEED and PROOM.

8.5 DMS tec

8.5.1 The Product Data Backbone Strategy

The documents that are created along with the workflow of technical organizations are all handled separately. The CAD/CAE data goes in PDM, ERP deals with the production and supply chain and CRM deals with customer facilitation. The traditional standalone DMS systems cannot handle this type of documentation at a larger scale because of its control over a limited part of document flow. (Merja Huhtala, 2012). A correct way to address this is to make a unified context of all the product's info and documents by a Product Data Backbone approach.

Similar to a humanly backbone structure it provides a creates digital relationships across relevant information for product and show their dependencies to initiate workflows. For example, if we must notify a developer that test has failed, for an assembly designed by him or when the technical development team make some changes to a particular part. The people in this chain do not have to put together the information from various sources together.

8.5.1.1 Working Difference between DMS(traditional) & DMStec

The conventional DMS relies on capture, store and retrieve method that is without index, it works on the methodology of keyword indexing and tagging the file which is not enough. These large unstructured folders limit the control of versions since there are problems in approvals and change of workflow also. DMS tec relies on product structures creating links of documents with the technical structure, it makes the data visible end-to-end. (Wikramanayake, 2014)

This type of visibility on the level of machines, floors and infrastructure reduces the lagging and data syncs it also covers the entire lifecycle. It does not matter if you are handling only one assemble or a part of the infrastructure it is managed in such a way that it's detached from the document itself. It is managed with the metadata and linking.

Changing the 1:1 or 1:n relation with m:n relation.

Better explaining with an example below.

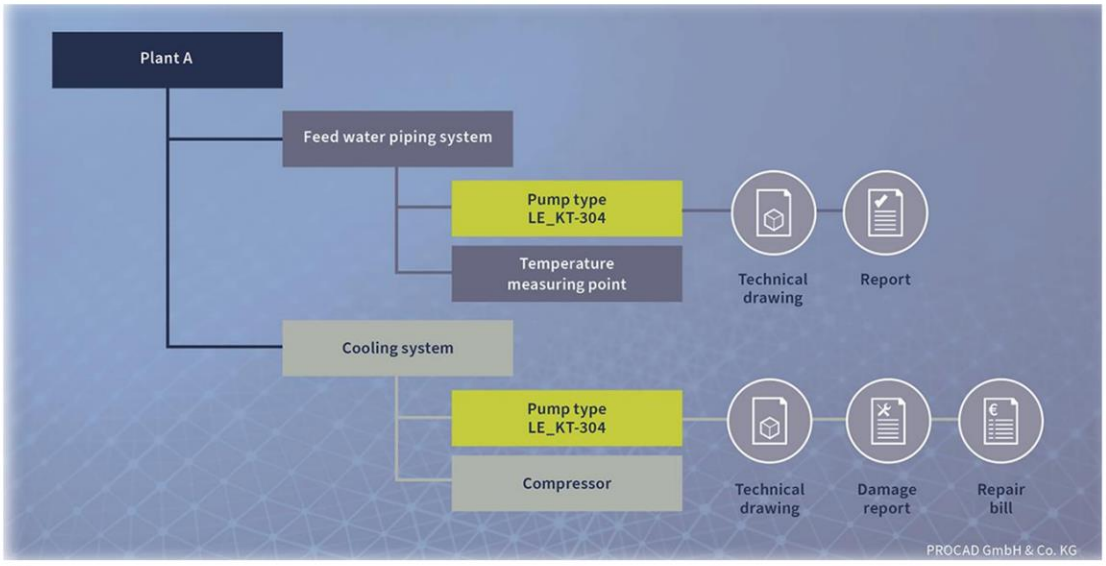


Figure 36 Document relation case study

If this pump has been set in 4 different locations in a plant, the identical specs are also stored in 4 locations inside the file structure under different designations of DMS. When there is an update or modification, in the conventional DMS systems it will be necessary to update all the different location documents. The conventional DMS system will use the tagging and indexing to find and update the specification, but it's not possible to establish a link between these location documents only by a tag.

But by Profile, we can have an intrinsic view of the plant, that is not attached to a document, we can get to know that it is the same document with multiple usages. In this way information is embedded with a context, dynamically. Controlling the workflows, accessing by a single point is easy by this logical relationship structure.

8.5.1.1.1 Practical View of PRO.FILE Search

The Profile Search bar is a powerful tool offering various options for a detailed search of parts, projects, documents, processes and tasks and access to PRO.FILE objects to be displayed.

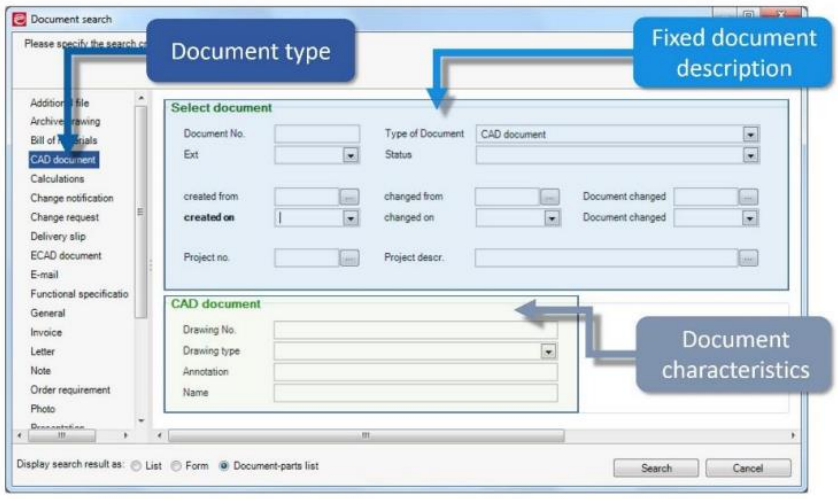


Figure 37 PROFILE document search form

Variety of options are shown to narrow down to the exact search that we are looking for, same is the form for searching the parts and projects. Further narrowing down of the search is also done by a 'full index search'. The input for the full-text search is connected to the input for the search form by an "AND"-connection logic. The full-text search allows users to search for keywords or strings that can be found either in the document or part description or even in the attached files on the file server.

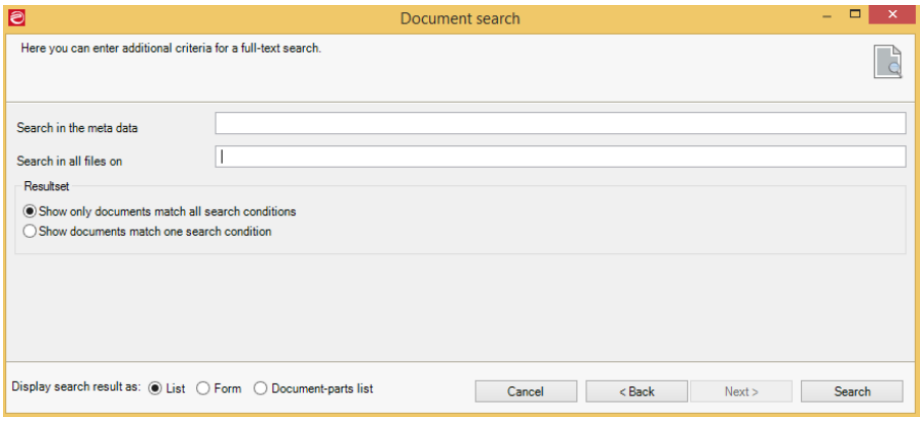


Figure 38 Full text Search form

The search term that is entered in the meta data field relates to the document description, the meta-data of the record. The descriptions of the document data base that are accessible to you will be searched for this search term.

The term for the 'search within the files' (e.g. a Word file or an AutoCAD file) is entered. All files accessible in the database that are linked to the document descriptions and that are saved via these document descriptions in PRO.FILE will be searched for the entered search term.

8.5.1.1.1.1.1 Smart Search

PRO.FILE also search for data records using a SmartSearch, it assists users a pre-saved query in interactive form that enables the SmartSearch with desired combination of the possibilities delivered by the search form. It can be set up to contain only the desired number of fields. Now, less fields must be filled in which drastically reduces complexity.

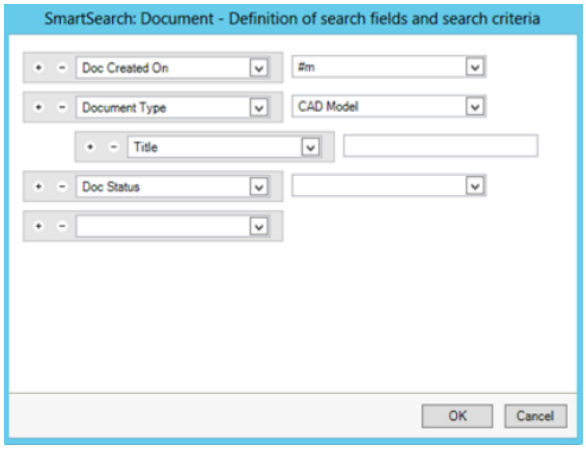


Figure 39 PRO.FILE smart search

8.5.1.2 Differentiated views of the same document

It is against productivity to make all the information available to everyone. Specific staff need specific information that is related to their job. Requirements of information can be very different depending on where an employee works. PROFILE's DMStec enables us to assign roles in the organization with a specialized view of relevant information – meanwhile ensuring that every file is being managed only one time inside the Product Data Backbone.

Different Point of views: development, design, manufacturing, and assembly

The developers have more use of the native drawings that are, in their case CAD models, line diagrams, wirings or a component's PCB layout. Their routine documents are very different from the ones used by the staff working on manufacturing phase or the assembling phase. They need documents of neutral format like pdfs or reports of assembly or production. Project management staff want a bird eye view for reviewing the on-time deliverance of projects. Managers also create their own documents for e.g., plans, calculations, and meeting summaries. Sales department require the contracts, engagement record with the clients etc. Sometimes they have the need for technical documents as well for references. Accounting/finance will require mainly the bids, order invoices and documents related to the items sold. Repair staff might require technical documentation of the specific parts that need to be replaced or repaired, its warranty, the installation guides etc. DMS tec provides relevant information to each staff without redundancies.

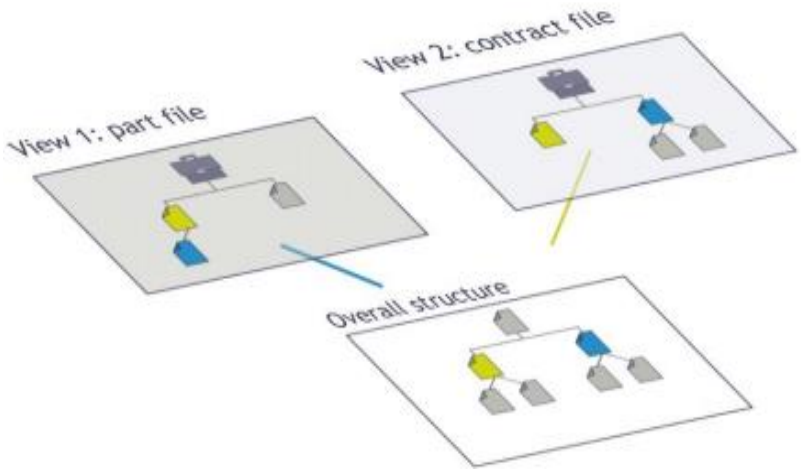


Figure 40 File structure and defining relevant views of same file

For example:

If during executing the on-site activities which is normally not in the scope of the product development phase. We come across a problem in functionality of the item/product, and it's discovered by a service call, this information will be conveyed, reporting all the way back into the design and manufacturing view. The strategy of product data backbone, with the help of its link to the field service management system, will notify the designated staff of processes that a certain item or component needs to be modified.

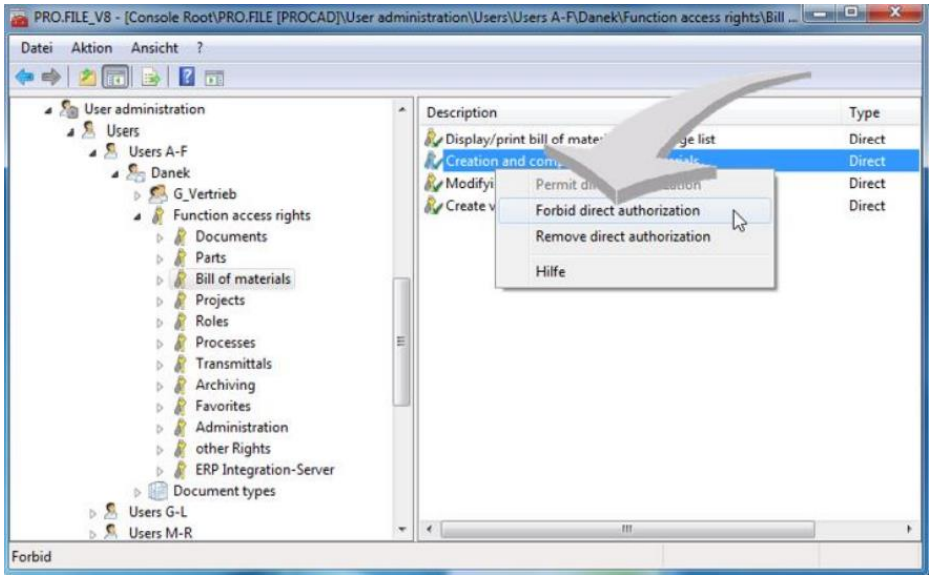


Figure 41 Differentiated views and editing rights for the different user groups

With the help of Management console (Admin configuration tool for PRO.FILE), Special rights can also be assigned to individual user to view, modify documents, projects etc. But the general procedure is assigning rights to a group e.g., Design team and adding the users in that group.

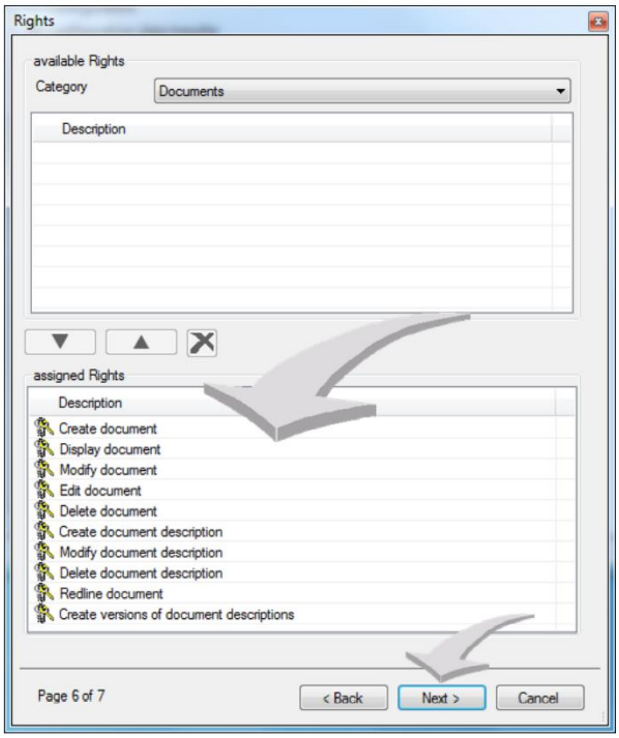


Figure 42 Assigning rights by using Management Console (Admin panel of PRO.FILE)

This was a demonstration of how product data backbone is utilized for specific views of the same file. It is a reasonable way to develop different relations between product structures, documents, and overall info.

8.5.1.3 Standardizing the document control

Every technical product needs to be completely documented, nowadays it is a legal requirement. Producers should show context into all walkthrough of their product development and structural interconnections. For the purpose of various audits and certification approvals required by the clients also. This type of system points toward a standardized procedure that needs to be adopted. Usually these are provided by the clients as requirements as well.

DMStec solution can be configured to receive these structures upon which it will create empty files to be used as order folders. Here a lifecycle file will be created for the system and over the period of time it will be filled with data by design team, planning department to quality assurance department. Following the documentation phase, it will be readily available for management purposes for production, repair/maintenance, customer services etc. A simple flowchart can be seen below.

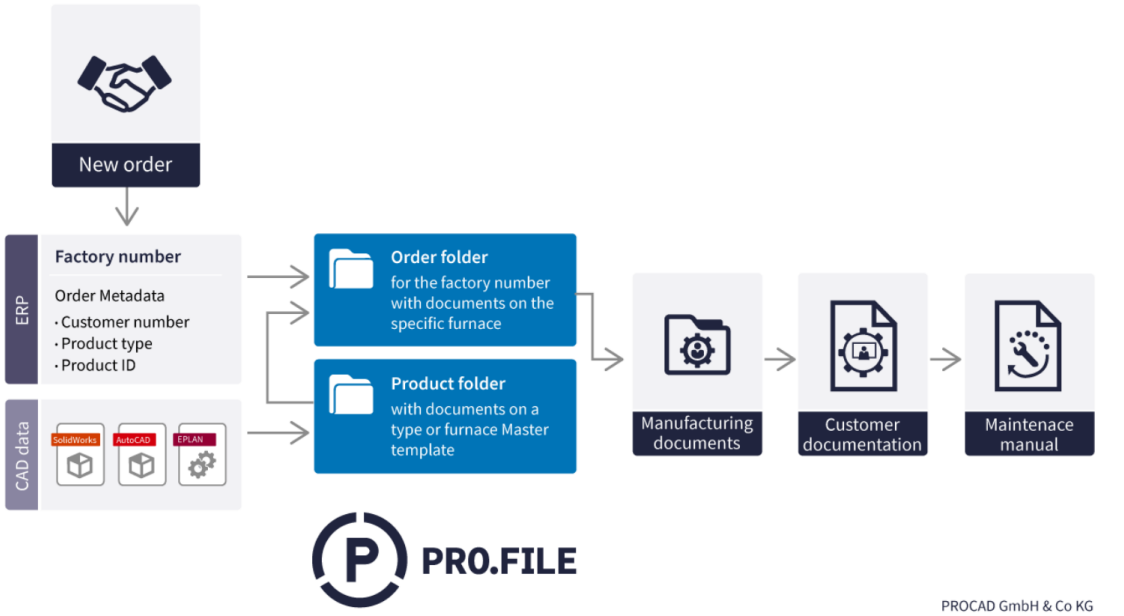


Figure 43 Digital document control in order processing for a make-to-order manufacturer on the example of PRO.FILE

In this way an 'information twin' of a simple product or a complete plant is developed, its complete lifecycle tracking is possible.

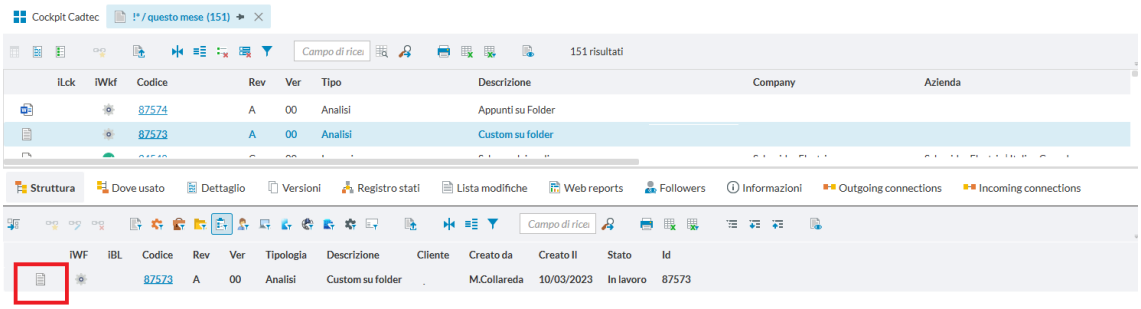


Figure 44 Example of an empty structure (marked in the red box) for an Analysis document to be inserted

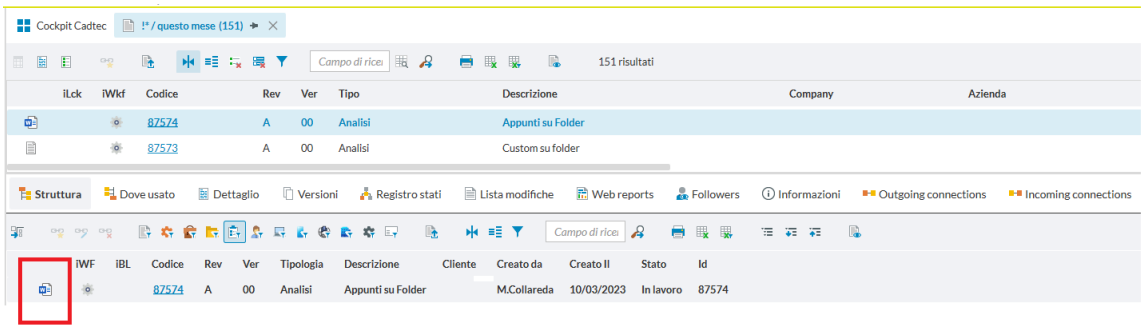


Figure 45 Example of a structure (marked in the red box) with a document inserted

DMStec has 'Bi-directional' integration system that can be configurated for authoring to make sure transfer of the information is autonomous into the project and respective documents. If configured to do so, it can identify emails as correspondence action and can interpret the metadata like sender, recipient, subject of mail, realizing if it has been sent to more than one addresses and store the mail as correspondence only one time. This way, an ECR (Engineering change req.) or an order is shown to all participants, system will read out the relevant article number, project, creator etc., even if this data is managed in other systems, like ERP.

Following flow chart shows the glimpse of status control in PROFILE PLM for a project/document.

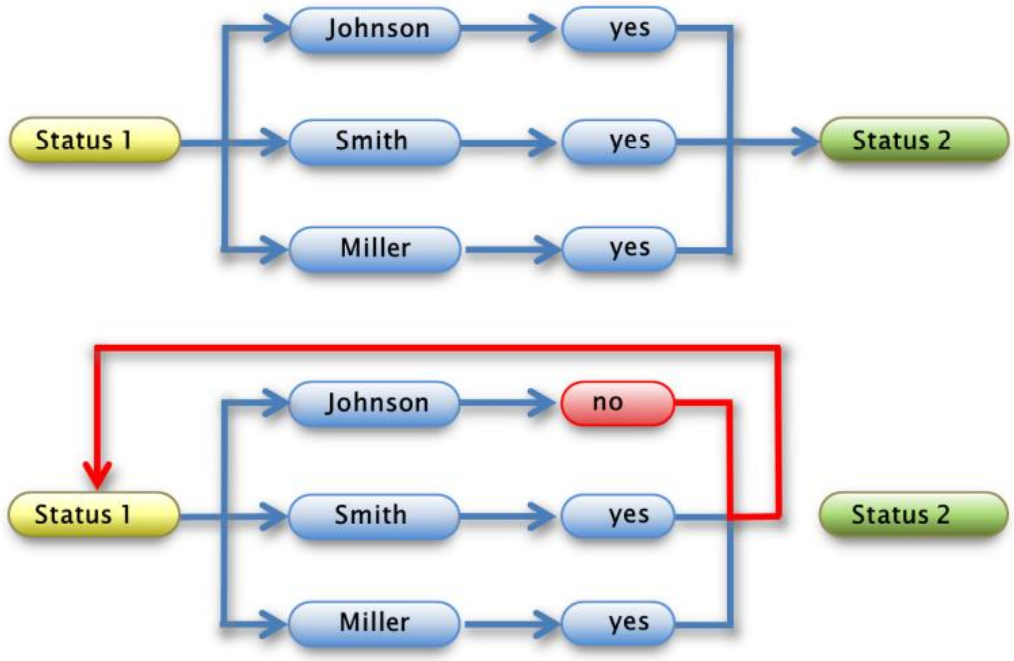


Figure 46 Control for status change of document/projects etc.

These logics are defined and customized according to the need of each company and can also be customized on a project or specific document level by using the Management Console (the configuration interface of PRO.FILE administration).

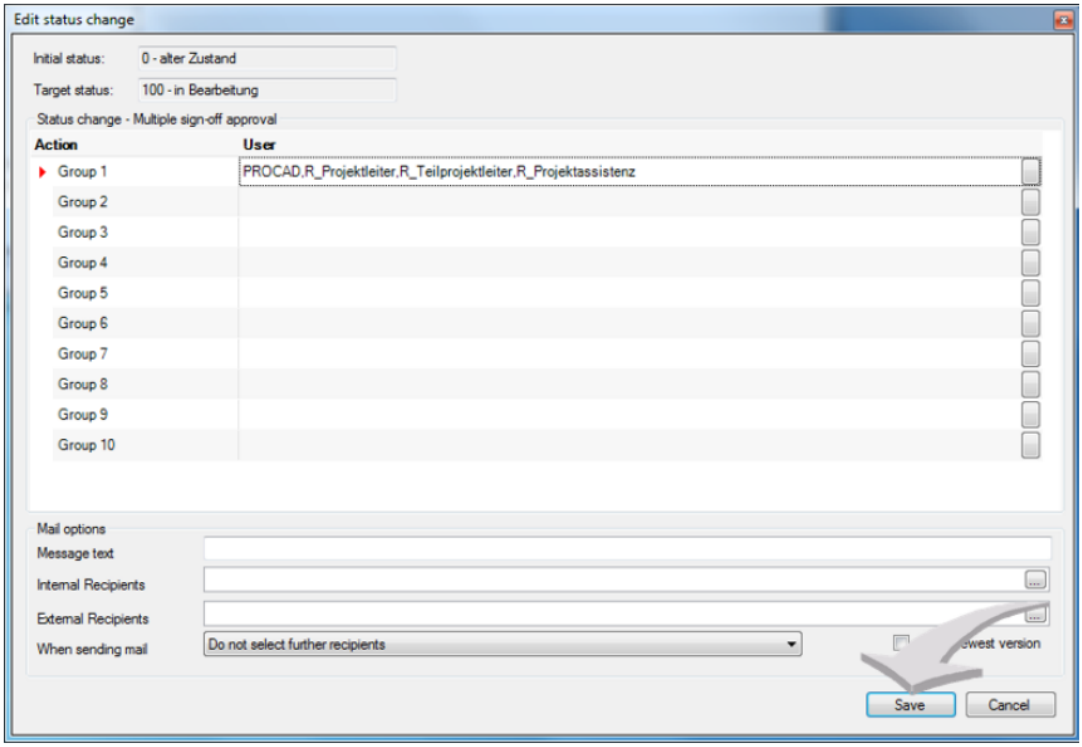


Figure 47 Configuring status change control with multiple sign-off and email alerts.

8.6 PROCEED

PRO.CEED are Application Packages which are developed to assist in digitalizing your main processes and workflows – doing gradual changes at your own speed. It designs logics create cockpits, defines processes, develop workflow menus, set predefined templates, setup automation features to map PLM processes with its custom-built application packages.

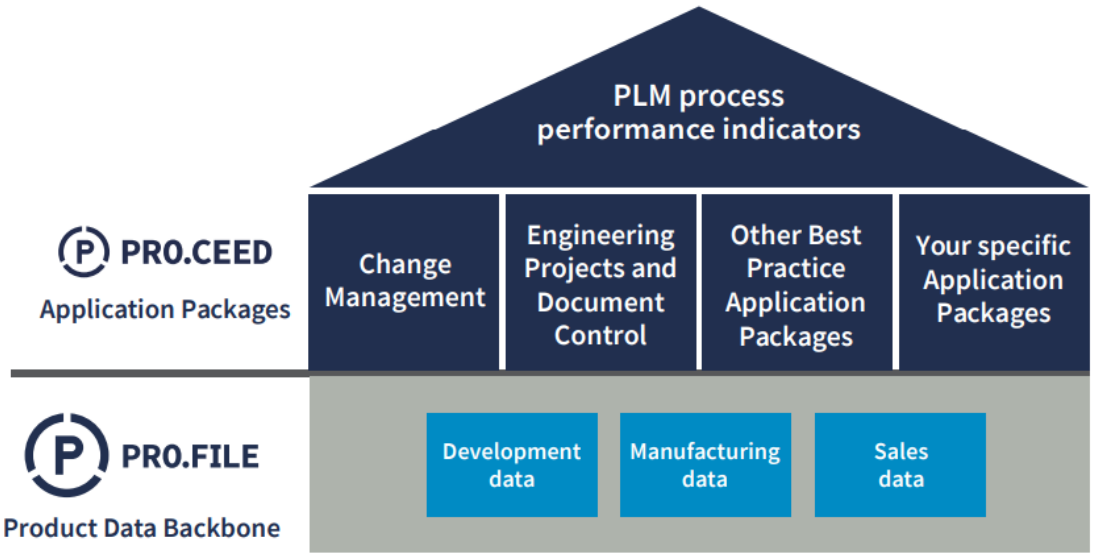


Figure 48 A holistic view of PROFILE with PROCEED

PRO.CEED develops on the already present data in PLM PRO.FILE. It consists of PRO.CEED Base and the PRO.CEED Application Packages. Every Application Package of PRO.CEED is developed from the experience utilized of numerous client projects, converting them in best practices. These application packages are preconfigured, are swiftly installed in PRO.FILE. PRO.CEED allows to improve efficiency of product's lifecycle management by automating respective processes.

The Best-Practice Application Packages:

PRO.CEED gives a rapid way of automating the processes of PLM in a way that it does not require extensive consulting. The Best practice application packages like "Change Management" and "Engineering Project and Document Control" will improve the way you organize your processes, document your activities, and create audit trails to ensure compliance.

8.6.1 Process Management with PRO.CEED

Features of the "Change Management" Application Package

• Standardize the engineering change process

• Automate documentation

• Formalize the decision-making process

• Complete transparency of schedules and costs

• Determine the impact of the change

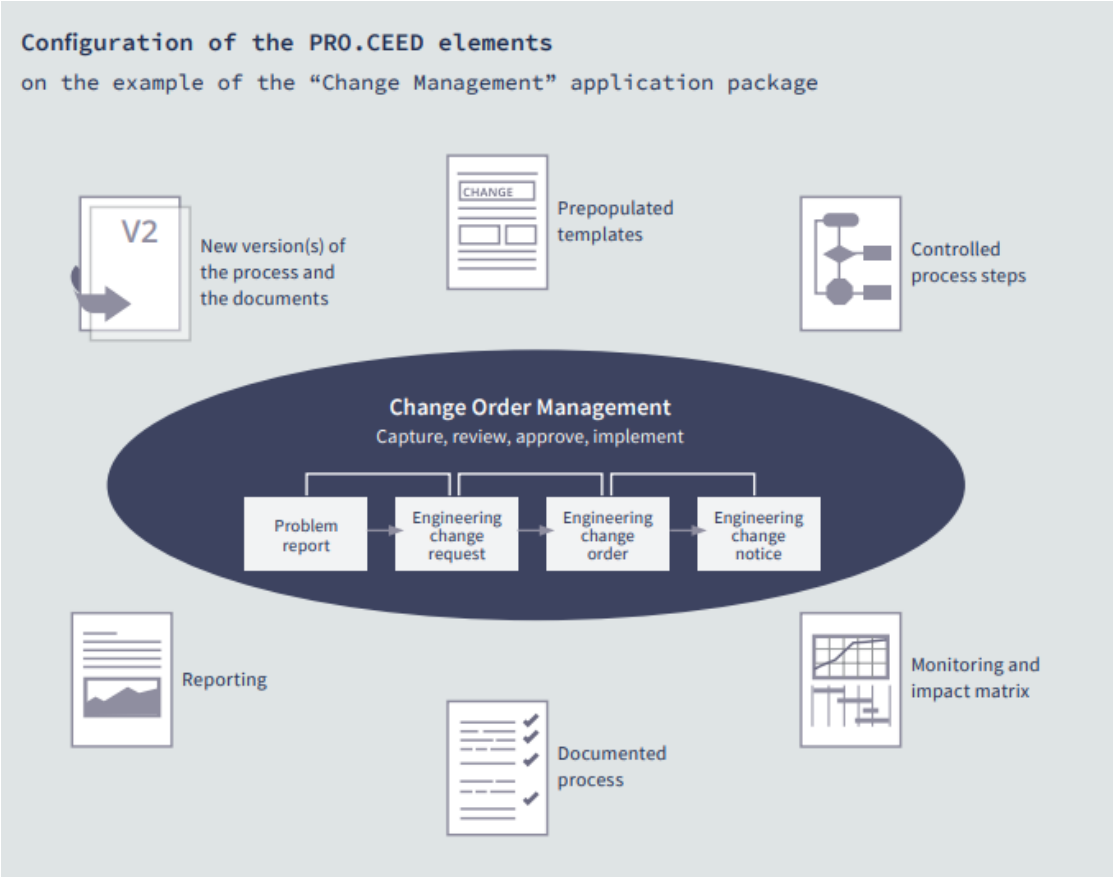


Figure 49 Visual Representation of Change Management flow and available options

The cockpit views of PROCEED allows us to make informed decisions based on current process status information.

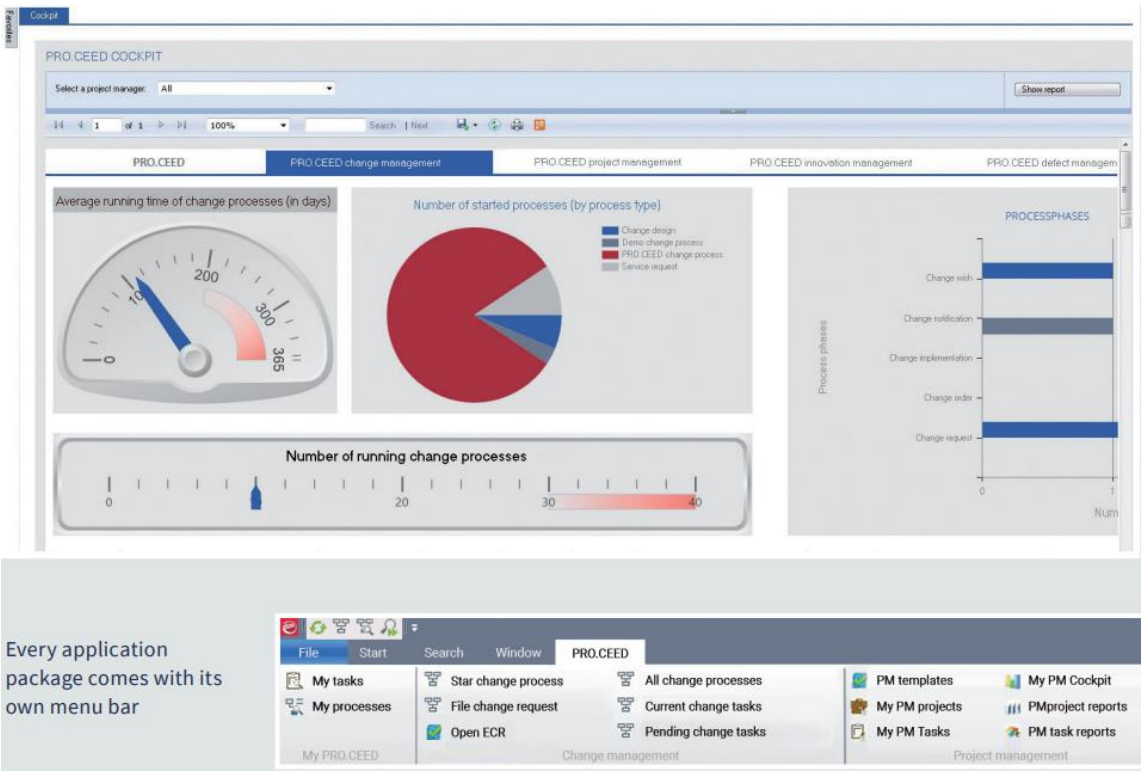


Figure 50 Cockpit view of Process Management

8.6.2 Project management with PRO.CEED

A common basis for the documents and data created in the different departments ensures full transparency and accelerates your workflows.

“Engineering Project and Document Control” Application Package

• Structured and automated control of the project progress

• Control project documents via task files

• Reduced processing times via better coordination of current activities

• Project cockpits

Figure 51 PROCEED extension toolbar

With PROCEED project related package allows us to create company defined project templates, project planning, and leverage on PRO.CEED monitor to track, manage, and document the project’s progress. The project participants are always supplied with latest documents and data at the time they initiate their task.

Figure 52 schedule variance dashboard

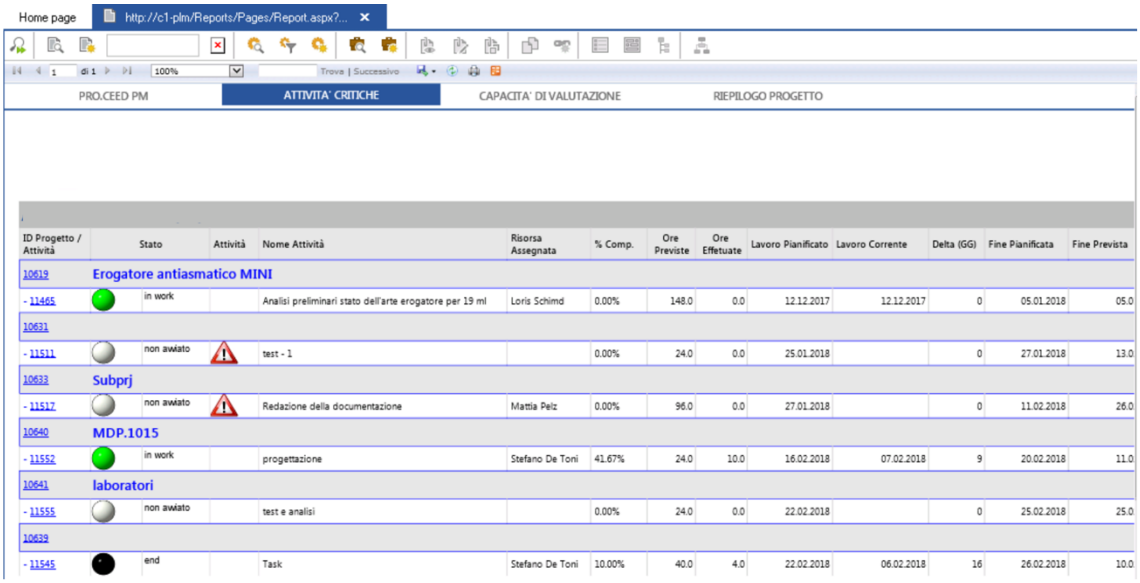


Figure 53 Critical Activity view

We can view projects and their tasks by highlighting task status as mentioned in the picture above. If the forecast of an activity does not respect the scheduled end, an alert appears in the icon of exclamation mark.

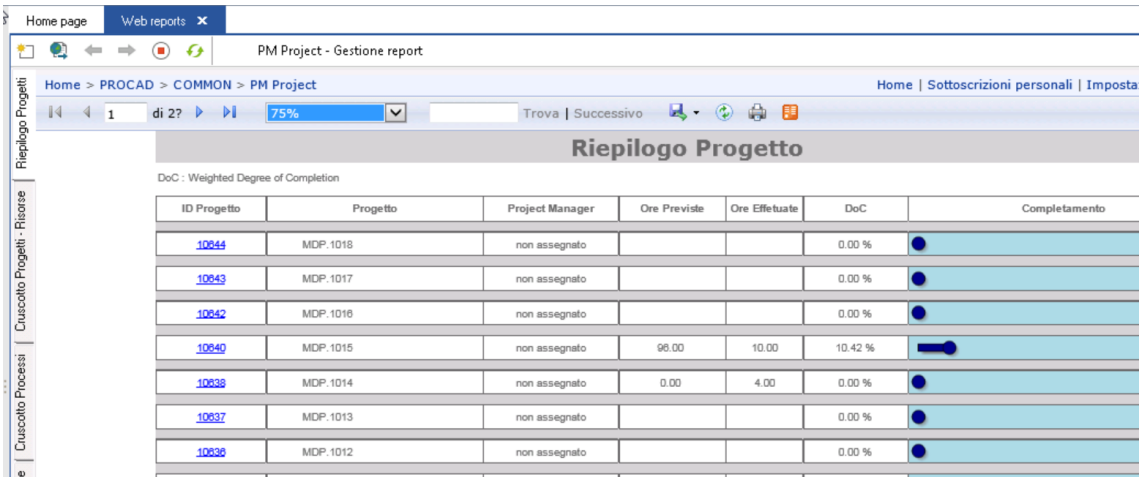


Figure 54 Project Summary view

Another view is the web report view as shown above. The report displays all projects with open or unperformed tasks, estimated hours, and performed hours. The % of completion is calculated as the ratio of the hours worked on the expected hours (the calculation is by way of example, the formula can be modified).

Just like for holistic views of processes PROCEED also assists with built-in dashboards and reports that enables to track progress of every project on any certain time for making informed decisions.

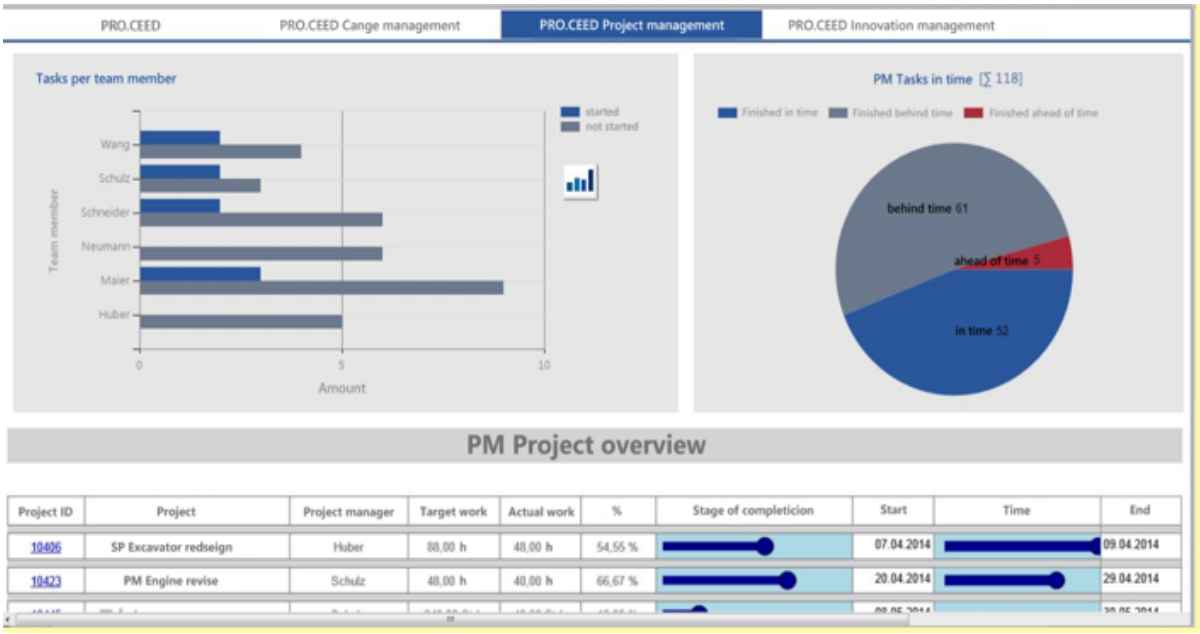


Figure 55 Cockpit view of Project Management

8.7 PROOM

PROOM represents the collaborative PLM system feature of PROFILE. Collaborative signifies that PLM processes have an extension beyond the walls of organization.

By Collaborative PLM , stakeholders, clients, and external suppliers are interconnected in the workflow of organization. The significant point in this case is to set the same regulations that are implement for the process control within the PLM.

PROOM is a platform extension for document exchange that is exclusively constructed to cater the requirements of manufacturing groups. It consists of Virtual Project Rooms that allows the organization to elect and control and user-authorization, providing total hold about who can view, edit, or send and what can be sent. It consists of Activity logs that are updated for every room to provide assurance in audit trailing.

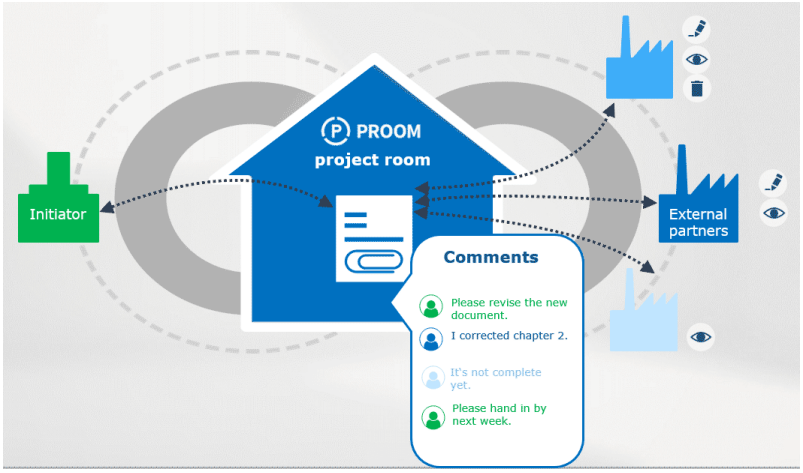


Figure 56 A graphic representation of a project room

8.7.1.1 Security Concerns and Compliance

Product-centered groups these days usually rely on variety of specialized teams deployed in many places. The documents in these cases handled throughout the development phase are modified by many partners operating also outside the corporate boundaries of the organization itself.

Here PLM is viewed as an integration and gives birth to Collaborative PLM. Here a business data-exchange tool is required at point of interface.

For a very lengthy timespan, email and File Transfer Protocol has been utilized for means of data transfer, but there are strong disadvantages associated with it:

- E-mail is insecure and dangerous environment for confidential information transferring.
- FTP loses controlling of file versioning, it has improper criteria for logging activities,
- FTP is very limited with uploading/downloading. (Peshraw Ahmed Abdalla, 2019)

Modern day businesses, share substantial files very frequently, with frequent management of document, versioning and controlling versions, giving permissions, creating separate project-rooms.

There are solutions like Dropbox that were basically invented for private usage only but later on they started to offer business versions too, they are better in accommodating information in confidential manner but setting up project rooms virtually for individual employees is something out of their capabilities which is a greater need of a product centered company. (Peshraw Ahmed Abdalla, 2019)

A multi layered security that does the data transfer and also tracks the logs of changes made to those files can be a solution, but the problem is that they are not integrated with the company's current PLM system which is already collaborative in nature. This does not ensure a smooth process experience while collaborations and exchange of technical documents like plans, RFPs, change orders, CAD drawings etc. PROOM on the other hand is an integrated solution for the PRO.FILE PLM. PROOM app is also developed for iOS and android for document exchange and messaging.

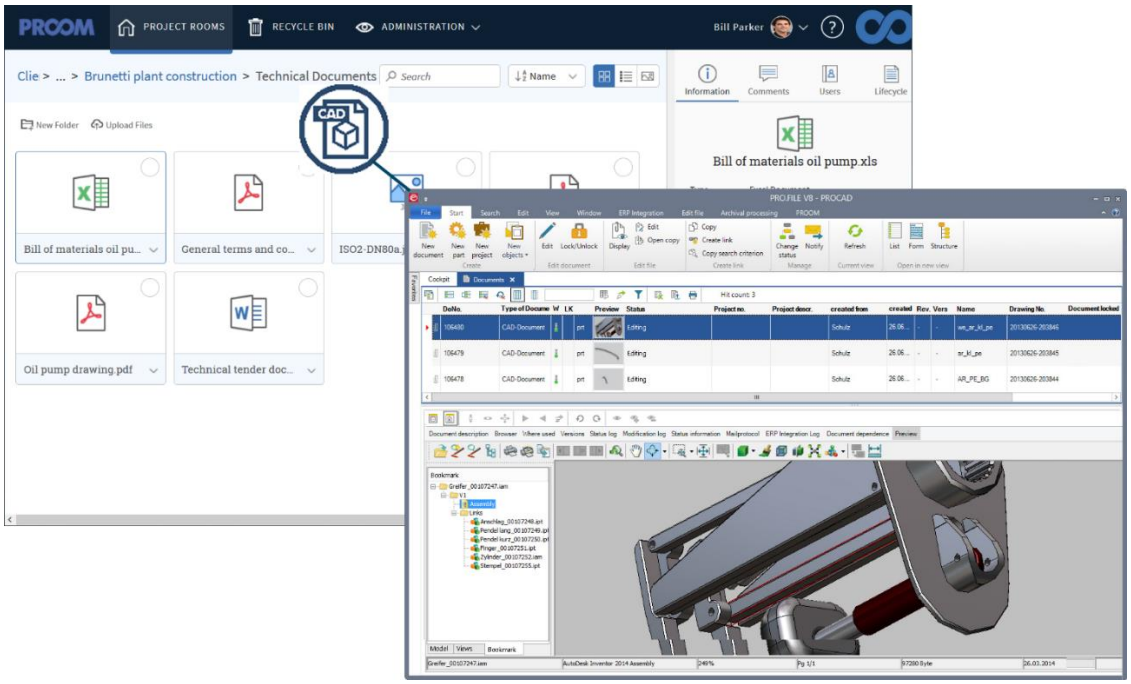


Figure 57 Working example of a project room

It has options to monitor and assign user-rights to ensure trails of activities in audit. Technical specs and data can be synched from this virtual room to make sure that design team is utilizing the updated version of file as there is not locally storing of the data like in an employee inbox. The users can work in independent mode and there is also option available to synchronize incase u modified something offline.

8.7.2 How Data is Transferred from PRO.FILE PLM to PROOM

There are mandatory procedural steps that are required to upload files saved in PRO.FILE into a project space in PROOM. Data is synched from PRO.FILE to PROOM by transmittals. A transmittal needs to be made in the first step for the transfer.

8.7.2.1 Transmittal:

Transmittals are distribution lists containing documents that are stored in PRO.FILE. Transmittals assist PROFILE to keep the record the distribution of documents with customers, external service providers and suppliers.

Big projects utilize transmittal to record drawing and document numbers along with their version and revision states, documenting the project's progress and responsibilities. Transmittals record the actual document versions at the time of distribution.

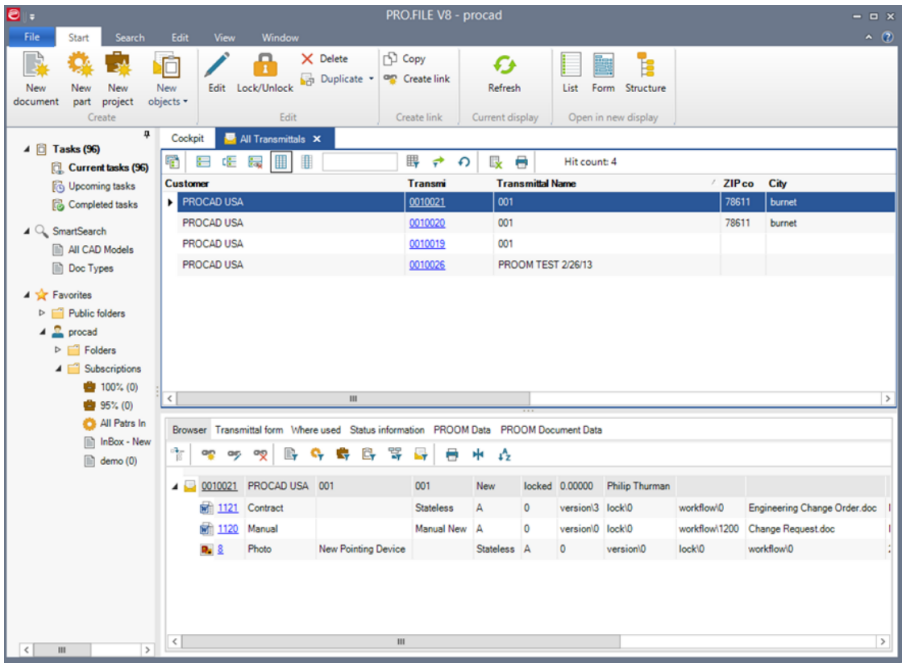


Figure 58 Example of a Transmittal

After creation of a transmittal, the documents that need to be sent to PROOM are linked to it and locked so they can not be edited by anyone else.

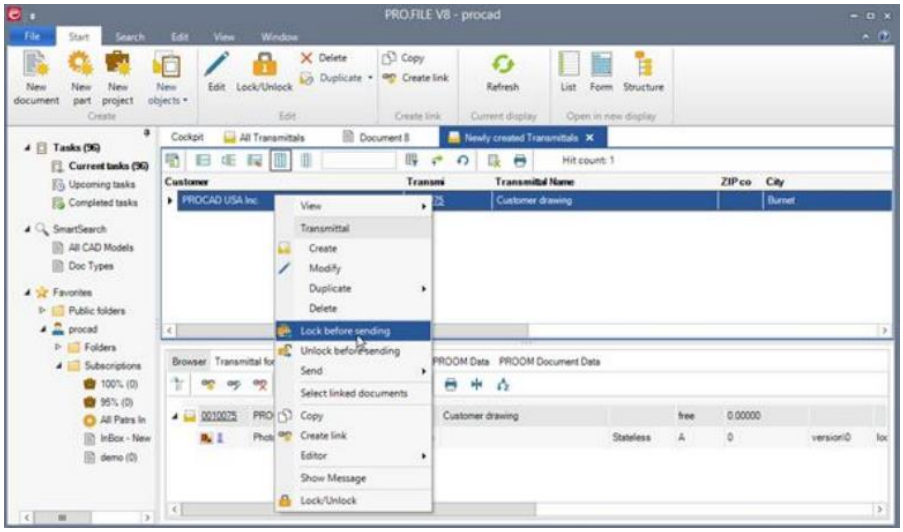


Figure 59 Locking a transmittal after linking the documents to be sent

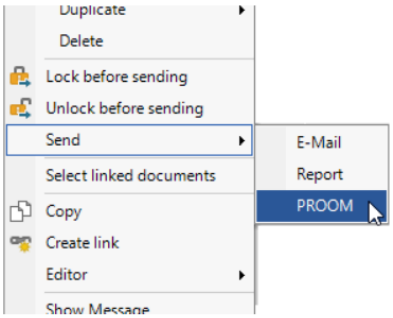


Figure 60 Sending transmittal to PROOM

After locking the documents to be sent to PROOM we have to send, publish and then specify the project rooms and destinations folders for receiving the documents. PROOM allows to even make the document available only for a specific amount of time after which the document will become invalid. Ensuring up to date information flow between stakeholders.

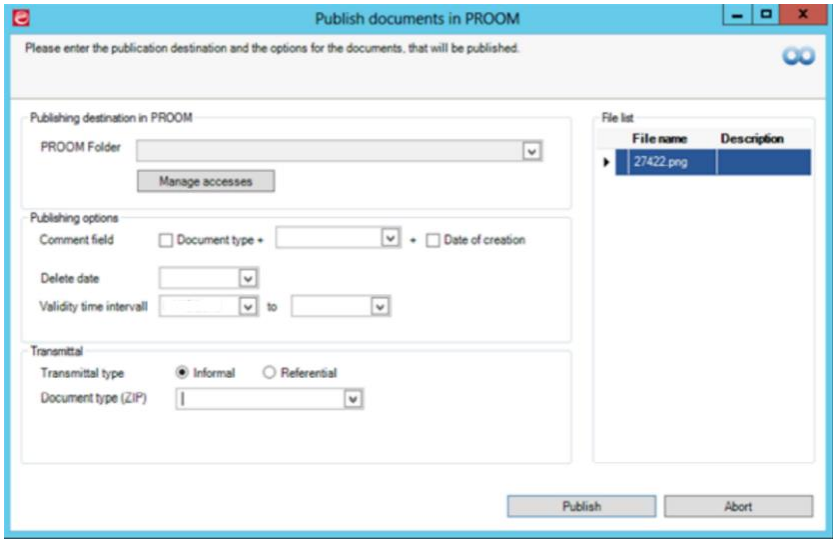


Figure 61 Publishing documents to PROOM

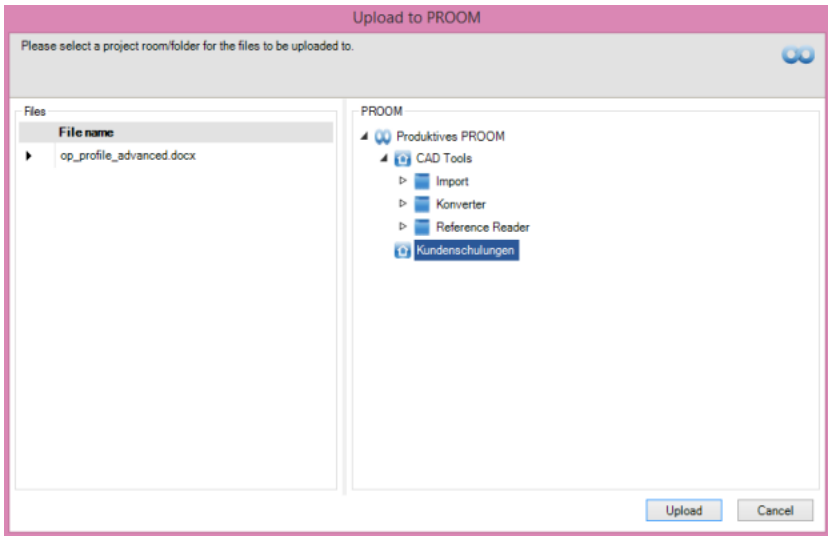


Figure 62 Specifying destination folders in PROOM

In PROOM, Project room managers can take advantage of a system of access-authorization to grant permissions about every project member and their capabilities of using every document. Specific login credentials are provided to the external stakeholders to access the data ensuring maximum security and privacy of data.

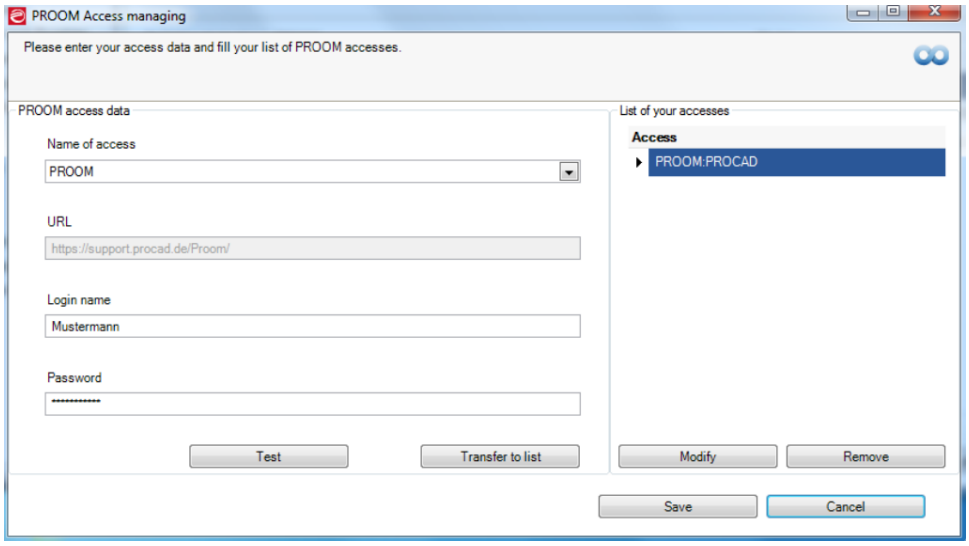


Figure 63 Managing Access in PROOM

Vice versa data can also be downloaded back from PROOM to PRO.FILE.

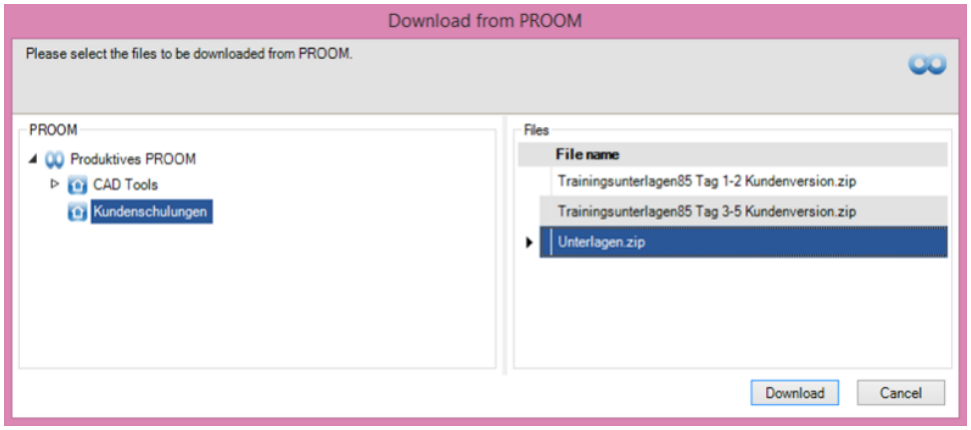


Figure 64 Downloading data in PROFILE from PROOM

8.8 PROFILE in the market of PLMs

After giving a comprehensive overview of PRO.FILE. Comparing PROFILE to the PLMs that were mentioned in the ending of chapter 5 it is safe to say that PROFILE is offering a lot of functionalities which are present as the main characteristics of market leaders. With strong hold on the product data management with its product backbone strategy, change management, project and process management by PROCEED and cloud services by PROOM. PRO.FILE functions are highly flexible and adaptable to custom modifications in line to the clients requirements.

The areas of improvement that can be considered are complete digital twinning with total real time data synchronization with live IOT products. Since the parent company of PROFILE is not affiliated or has developed a CAD software itself, first mover innovations in CAD integration can not be a competitive advantage for PROFILE like the market leaders we discussed above.

9 Challenges Faced

9.1 Problems faced by Clients and their adopted solutions

Apart from the generic inbound helpline, PRO.FILE facilitates its clients by a ticket portal that can be accessed by all the clients for opening tickets for any query or problem that they are facing so it can be responded to or solved in a quick manner. The tickets are resolved by helpdesk both of level 1 (basic problem and query support) and level 2 (in depth technical support) agents, PLM specialists and technical project managers that manage the tickets efficiently.

A summary of all the tickets opened in 2022 is showcased below.

Figure 65 Populating the ticket types

9.1.1 Errors:

The errors are problems that can be classified as bugs. In contrast to what is considered regarding bugs i.e., faulty coding, these errors are mostly caused by the integration problems as like every other software product, the integrations of PRO.FILE are constantly updating which causes problems in compatibility. These integrations can be of any type be it Microsoft variants, antivirus policies and CAD updates.

For these reasons PRO.FILE focuses heavily on continuous improvement and constantly releases its Service Packs with latest updated integrations periodically.

9.1.2 Configuration:

Configuration queries on one hand are queries related to buying a new license of PRO.FILE increasing a new account, its settings etc. On the other hand, configuration are issues or queries raised for configuring the settings of use. For example, creation of customs modifications according to the working standard of the specific company, massive database level updates or integration of highly specific/ uncommon software used by the company.

Cases like these are evaluated by the flow of helpdesk agents from Level 1 to Level 2 and finally to a PRO.FILE specialist or Project manager that take into account these specific cases and produce analysis documents and estimates the work hours. PRO.FILE modifications are highly flexible and adapt to the user needs.

9.1.3 Information:

Clients can also open tickets for basic user information and FAQs, these clients can be newly inducted employees that are new to PLM or old employees asking information according to their observations.

For reducing these types of errors, PRO.FILE works on continuously updating and publishing the 0 Level helpdesk support which in common terms is known as User Manuals and Guides.

9.1.4 Personalization:

9.1.4.1 Understanding of Personalization with or without Programming

In literary terms it can be defined as the steps taken to get accordance with a task or user requirement. (Stark, 2018)

In the terms of business and managing, customization is the designing and developing of any product in order to get in line with the client's specific needs. (Law, 2016)

In the sector of IT, the terms like configure, modify, developing in-house or OOTB(out of box) are various terms that explain customization.

9.1.4.2 Out of the box

Like the name says, an OOTB is in simple words ready-made and catered for your business. It is implemented swiftly and does not require great efforts in installation. This type of solution is generally for organizations that have a standardized operating process and they don't need many customizing.

SAP defines customization as a parametring and adapting of IT product to the needs of the company with the help of some tools. (Thomas, 2003)

On the contrary leading PLM solution seller 'Siemens' explains customization as adapting, extending, modifying the IT product by using various means like tools but including coding/programming. (Siemens, 2008)

Defining the two types together with the help of visualization below.

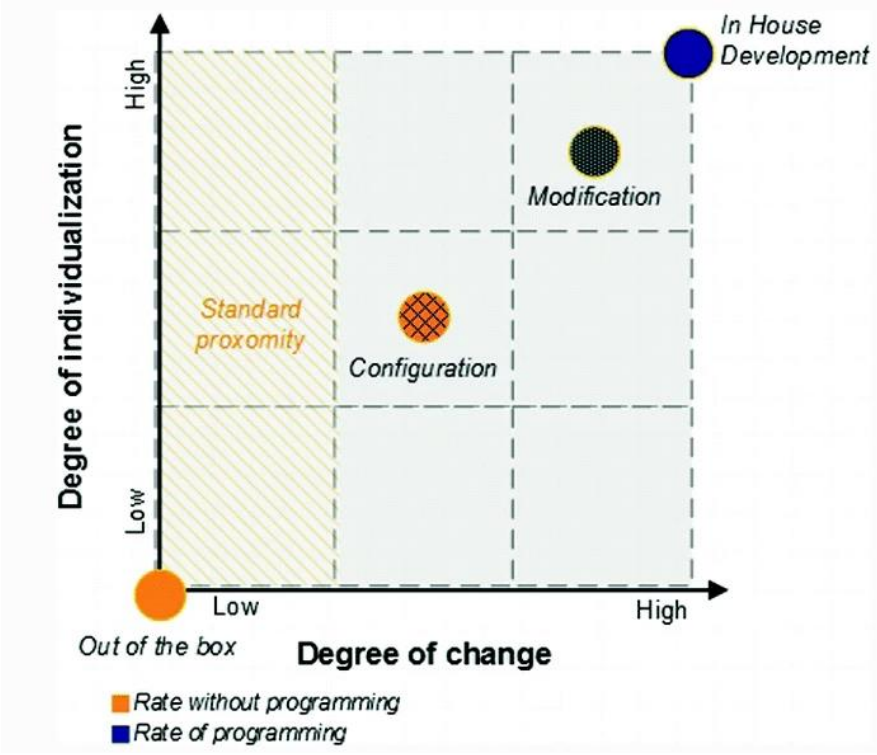


Figure 66 Code vs No Code

Personalization here refers to user request that are not big enough to be classified as configuration or custom modifications. They are small changes or updates like creating new user, updating user groups, mailing lists, workflow changes deleting or changing user rights.

Some of these queries although are also solved by the IT staff present in the client company that also serves as the role of Admin PRO.FILE but when raised to us, are solved with equal priority.

PRO.FILE is working to reduce such tickets and with the release of the new version of PRO.FILE called NEXT 10.4, as the aim of it now goes towards being low code to no code. The user interface, dashboards, administrator panels and configurations are extremely becoming user friendly.

As a result, the users of NEXT 10.4 also experience lesser issues and lower tickets are raised by these clients who have shifted to the newer version of PRO.FILE PLM. Following is a report that illustrates the number of tickets opened by users of different versions of PRO.FILE.

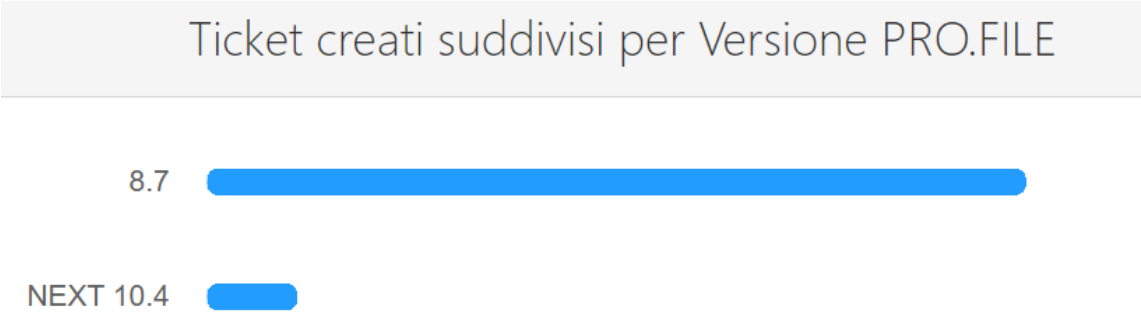


Figure 67 Comparison of tickets w.r.t PROFILE Versions

One reason for this extreme shrinkage (81.5 % vs 9.3%) in tickets is because there are not a lot of clients who have shifted to NEXT 10.4 as well. But still there is a reduction in the amount of tickets for the users of the updated version of this PLM.

9.1.5 User Errors:

These type of errors are due to the users who mistakenly open tickets as ‘errors’ instead of information or have made mistakes in execution because they are missing something in training for the usage of PLM.

PRO.FILE is minimizing these types of errors by conduction trainings, workshops and constantly working on increasing the amount of Level 0 helpdesk by publishing and reviewing more and more user guides.

10 Why PLMs? External and Internal Forces Involved

10.1 Internal Forces

There was a time when reducing the operating cost by enhancing efficiency was a main source to achieve a competitive advantage. Now factors like innovation of the product, maintenance of close relations with customer base alongside the operating excellency has become key factors that are internal to the dynamics of a company.

10.1.1 Innovation Needs

According to the study 'theory of ideas' which was given by Paul Romer allowing people to be knowledgeable increases innovation and enhances their capacity to create new products/services. In an innovative environment that supports inclusion of ideas, all players remain informed which is beneficial.

Implementing PLM software in a company can be driven by the need for innovation.

If a knowledge management system or a knowledge base is set up in the company, it will be streamlining the product development process and allows players to bring new and innovative products to market faster. It can also provide accesses to data and analytics/insights that help companies identify customer needs and preferences, which can inform the product development process. With PLM software, companies can create a culture of innovation, encouraging employees to think creatively and come up with new and innovative ideas. The implementation of PLM software can enable companies to stay ahead of the competition by providing them with the tools they need to innovate and create new products that meet customer needs.

10.1.2 Customer Intimacy

Customer intimacy is another internal force that can drive the implementation of PLM software in a company. PLMs can help companies gain a deeper understanding of their customers' needs and preferences. Escalating from make to stock and made to order type of strategy to mass scale customization and personalizing is now the new trend. With PLMs, companies can capture data and analytics on customer preferences, which can inform the design and development of new products, this is a valuable source of knowledge since they are the actual and first hand users of the item developed. The upstream and downstream communication will be made more streamlined to collaborate more effectively with customers, allowing them to co-create products that meet specific customer needs. Organizations can build stronger relationships with their customers and develop products that better meet their needs, enhancing customer satisfaction and loyalty. (Farhad Ameri, 2005)

10.1.3 Operational Excellence

Looking at the chain of activities from the value chain point of view, the processes that are adding value to the chain is one way to gain competitive advantage. For example looking at highly matured and technical CAD tools which are fulfilling the activity of designing a product but in the value chain what is required is the integration and streamlined communication with the other processes for efficiency.

Such a knowledge base platform will help companies achieve operational excellence by streamlining product development processes and reducing waste. It is known that wasted times in the most businesses is attributed to the lack of information which is unified as the knowledge base. Looking for data, translating it, reinventing the already present knowledge are problems that decreases the value of the chain. PLMs automate many manual processes, such as document management and change control, reducing the risk of errors and improving efficiency. With PLM software, companies can manage product data more effectively, reducing the risk of duplicate or inconsistent data. It can also provide real-time visibility into product development processes,

enabling companies to identify and resolve bottlenecks quickly. Organizations can achieve operational excellence, reducing costs, improving quality, and increasing speed to market.

10.2 External Forces

External forces are elements that can have an impact on an organization's operations and decision-making. There are several outside factors that could affect the software's implementation. Regulations, customer needs, competition, technical improvements, economic variables, industry standards, vendor connections, alliances, and other factors are just a few examples of these forces at work. The decision to adopt new software by a corporation and the way it is implemented can both be significantly influenced by each of these forces. Companies that want to make educated judgments regarding their software investments and guarantee successful deployment and uptake must comprehend these external forces.

10.2.1 Globalization

The increasing globalization of markets can create pressure for companies to implement PLM software that enables them to manage their product development and manufacturing processes across multiple locations and time zones. There are increases in resources cost for which the manufacturing companies now do not rely on local suppliers, but they search for cheapest resources worldwide. PLMs can help companies streamline their operations, reduce costs, and improve product quality, which can be critical for success in a global market by making the knowledge base co-related. Additionally, it can provide companies with real-time visibility into their supply chain, which is essential for managing global suppliers and partners. (Anneli Silventoinen, 2009)

10.2.2 Complexities in Product

Since the products are becoming more complex and increasing in the number of parts with technicalities in design. It is becoming very difficult for the organizations for management of their development and production process without the use of specialized software like PLM. In a complex product, there is probably going to be greater variation across the versions through as designed, as built, as installed, and as maintained. The availability of decision supporting systems that allows for the reusing of previous information is crucial to the effectiveness of decision making in complicated design environments. A complicated product is more likely to have engineering modifications, and an intelligent change management system is needed to effectively manage the changes.

PLMs can expedite the product development process, enabling to bring more complex products to market faster and with greater accuracy. (Farhad Ameri, 2005)

10.2.3 Shrinking Product Lifecycles

With the speed of technological changes and the ever-increasing competition in industry, the product lifecycles are shrinking. Companies are almost always under pressure to bring items to the market swiftly and to update their product lines in a frequent manner. There is always a tradeoff between time-to-market TTM and cost of developing, quality vs performance of the product. PLM with its knowledge base assists companies in management of their product data and collaborate more effectively, enabling them to speed up their product development and launch processes. It’s crucial for players to stay forward in the competition in a market that is rapidly changing.

10.2.4 Supply Chain Push

The never-ending drive to reduce cost and efficiency improvement in the supply chain in modern day market requires tools for supplier management in an effective manner. With PLMs real time

visibility can be tracked for supply chain performance monitoring and to discover more opportunities for betterment.

The capacity of sharing intellectual-assets (for e.g., technology know-how, product knowledge and customer requirements) with suppliers is the crucial determinant of successful joint NPD practices. Having a knowledge management system like PLM promotes such practices. (Anneli Silventoinen, 2009)

10.2.5 Issues related to Environment

Alongside the greater concern regarding environment impact of production and use, companies are under pressure to identify, evaluate, rectify and design more sustainable products and to manage their environmental impact throughout the product lifecycle. Organizations are focusing on LCA i.e., Life Cycle Assessment techniques. For which detailed implementing requires info about inputs/outputs, emissions in all processes and sub processes. PLMs can help in LCA process with their efficient integration system because it maintains a knowledge base with accurate data, past knowledge which can help updating the LCA assessments dynamically. Organizations track the environmental impact of their products and make more sustainable design and manufacturing decisions. It can be significant for companies that have to demonstrate true commitment to sustainability in front of customers, stakeholders, and regulatory authorities.

11 Conclusion

The PLM industry is growing rapidly as companies look for ways to improve their product development processes and stay competitive in the global market. The demand for PLM software solutions is expected to continue to increase as companies seek to digitize their operations and automate their workflows. According to 'MarketsandMarkets', the global PLM market size is expected to reach USD 73.7 billion by 2024, growing at a CAGR of 7.8% during the forecast period up to 2019-24. (MarketsAndMarkets, 2023)

Figure 68 PLM growth by MarketsandMarkets

Following graph shows the growth of PLMs market specifically.

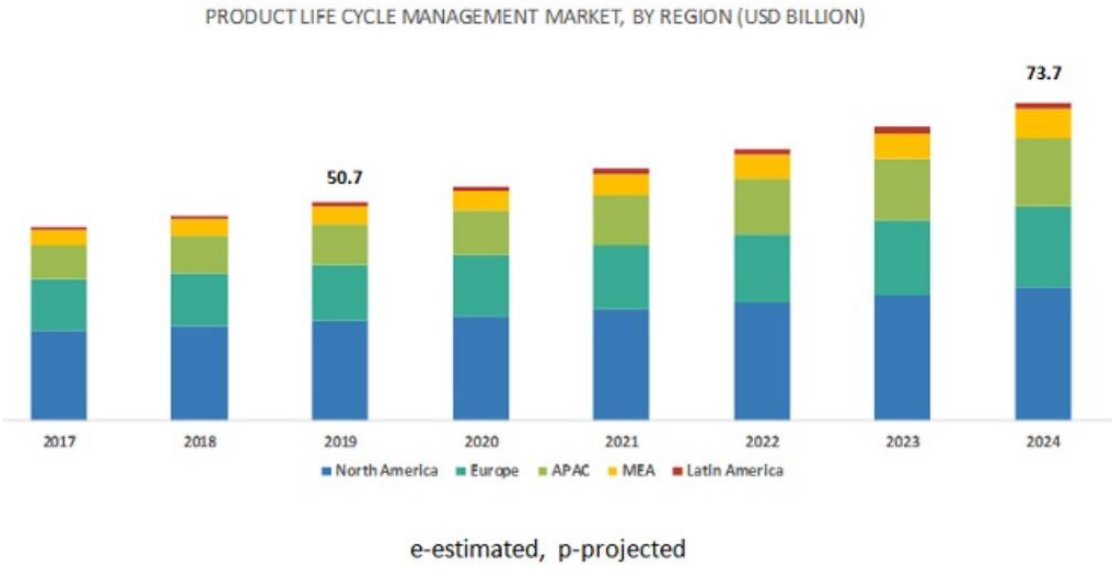
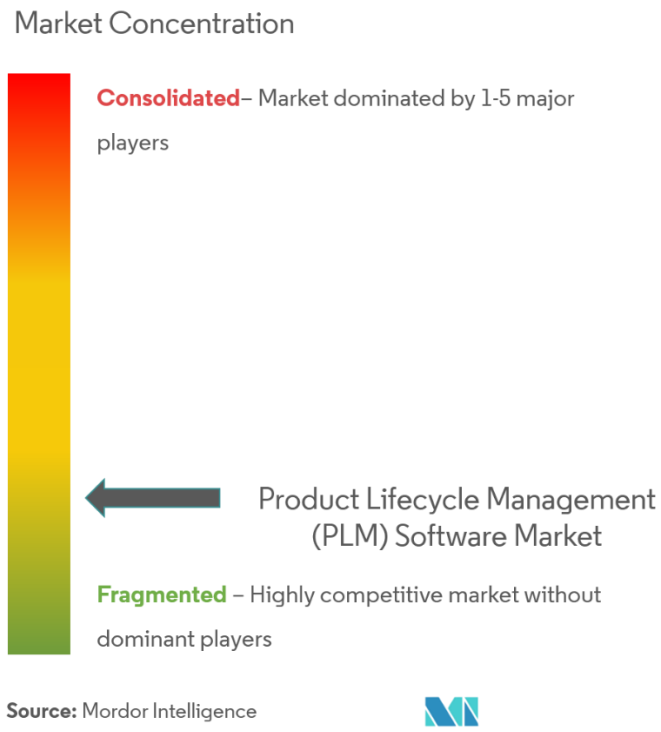


Figure 69 PLM market growth by MarketsandMarkets

The PLM market is expected to see several developments in the future, driven by the increasing demand for digital transformation and the emergence of new technologies. Some of the key further developments expected in the PLM market include:

- Greater integration with emerging technologies: PLM software is expected to integrate more closely with emerging technologies such as artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) to provide more advanced functionalities and insights.
- Increased focus on sustainability: PLM software is expected to incorporate more features that enable companies to manage their environmental and social impact by tracking and reducing their carbon footprint and managing sustainable supply chains.
- Further growth in cloud-based PLM solutions: The adoption of cloud-based PLM solutions is expected to continue to grow, as businesses seek more flexible, scalable, and cost-effective solutions that enable remote collaboration and data access.
- Focus on usability and user experience: PLM software is expected to place greater emphasis on usability and user experience, with more intuitive interfaces and easier integration with other enterprise systems.

According to a recent study report by Mordor Intelligence conducted in 2022 it was made clear that the PLMs still have a long way to go before becoming a saturated industry. (Intelligence, 2023)



PRO.FILE is well-positioned to take advantage of this trend, as it offers a comprehensive PLM solution with a range of features that can help companies improve their product development processes. The software's strong focus on data management, CAD integration, document management, and workflow automation makes it an attractive choice for companies looking to streamline their operations and reduce costs.

In addition, PROCAD, the company behind PRO.FILE, has a strong track record of innovation and has been continuously developing the software to meet the changing needs of its customers. This focus on innovation and continuous improvement is likely to help PRO.FILE remain competitive in the PLM market and ensure its relevance in the future.

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