CHALMERS
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Product Lifecycle Management pre-study

An investigative case at Industrial Automation, ABB AB

Master's thesis in Product Development

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Abstract

The concept of Product Lifecycle Management (PLM) is becoming popular than ever. Industries are growingly understanding the necessity to incorporate this strategy as an essential business element. This research presents an overview of how a backbone PLM is seemingly significant for ABB Industrial Automation, Business Unit X (masked name). The internal organizational quest to identify a central repository to maintain product-related data and to re-establish ABB products as the central source of truth is investigated in this pre-study. In the earlier phases of this study, the current organizational landscape is presented from the qualitative data gathered through interviews, existing literature, and benchmarking. This is then followed by analyzing the latest industrial trends and ABB's global vision to achieve a completely data-driven future. A thorough study of various legal and sustainable requirements are also projected in this pre-study. The gaps existing between the current IS/IT landscape and projected future requirements are bridged by proposing a PLM solution, identifying a suitable vendor, and calculating Return of Investment. Throughout the report, the complexity of adopting a PLM concept is presented as well as the benefits and uncertainties which come along with such an investment.

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Lokesh Nandakumar & Varun Radhakrishnan Hariharan, Gothenburg, 2019

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ABBREVIATION

ALM - Application Lifecycle Management

BOM - Bill of Material

CRM - Customer Relationship Management

EBOM - Engineering Bill of Material

ECR - Engineering Change Request

ECN - Engineering Change Notice

ERP - Enterprise Resource Planning

IA - Industrial Automation

IoT - Internet of Things

IS/IT - Information Systems/ Information Technology

PDM - Product Data management

PIM - Product Information Modeling

PLM - Product Lifecycle Management

ROI - Return of Investment

SCM - Supply Chain Management

STEP - Standard for The Exchange of Product data

1 INTRODUCTION

The Industrial Automation unit within ABB, where this project was initiated has considered a PLM/PDM solution for a long time for increased efficiency and reduced lock-in to external partners. Through this work, we tend to identify the AS-IS situation, current pain-points, and requirements for the business units PLM/PDM processes and future endeavors. This is then followed by defining the TO-BE roadmap, aligned with ABB Strategy for R&D / Engineering domain, including a business case & associated cost. The support and collaboration in this pre-study are further extended by:

- Leveraging ABB enterprise architecture capabilities and target platform landscape
- Utilizing ABB global partners with immense experience in PLM/PDM domain.
- Collecting knowledge from other Business Units, where similar pre-study and implementations were initiated.
- Interviews with divisional subject matter experts.

1.1 BACKGROUND

Product Lifecycle Management allows companies to manage their products across their life cycle – from the earliest idea of a product all the way through to the end of its life. This is one of the most important activities in any manufacturing company. PLM is equally important as the other activities such as ERP, SCM & CRM. But PLM addresses the most important aspect of the company; its primary source of value and wealth, the product, which makes the PLM the most important asset and key activity for the company.

As a technology solution, it establishes a set of tools and technologies that provide a shared platform for collaboration among product stakeholders and streamlines the flow of information among all the stages of the product life cycle.

In relation to the closing of knowledge loops, (Ameri & Dutta, 2005) also define PLM in terms of a technology solution, establishes a set of tools which together deliver a shared platform for collaboration among stakeholders as well as guides the information flow along various stages of the product life cycle.

As defined by CIMdata, PLM is usually misunderstood as a definition of technology; but wherein it is defined as a business approach that resolves the issue of managing a series of products and all the functions associated with them such as creating data, maintaining them through the products' life. In the PLM approach the process of the more critical than that of the data managed in the process.

(Ameri & Dutta, 2005) provide a different aspect by representing PLM as a competitive advantage for the company, which is unique through its adoption, and mentions that the cultural and social aspect of PLM is equally significant to its technological aspects.

It is suggested by (Ameri & Dutta, 2005) that it is required to create an environment that is characterized by systematic capture, management, and dissemination of knowledge by eliminating the inadequacies that time, distance and differing professional disciplines introduce into the value chain as it helps in eliminating and reducing waste in the value chain. (Ameri & Dutta, 2005) also convey that focusing on the products and having a common mission around the products represents much more than a philosophical view and is a basic requirement for success in the market, which manufacturers are realizing today, more than ever.

It is pointed out that waste in the value chain shall be reduced by creating an atmosphere to systematically capture, manage, disseminating knowledge henceforth, eliminate various deficiencies at that point in time (Ameri & Dutta, 2005). Some of them point out to varying professional disciplines placed within the value chain. In addition to this, (Ameri & Dutta, 2005) also discuss that manufacturers are understanding the fundamental to success is to focus on the product and is much more than a philosophy. This is relatable to a PLM implementation perspective as the core of business success along with many other considerations, is to develop a deep focal point on the various aspects of a product from ideation to end of its lifecycle.

Data and information management in large enterprises with worldwide market presence is being discussed as one of the most prominent topics of interest in Product Development. This includes Big Data, IoT, Product Lifecycle Management, Industry 4.0, and Master Data Management.

Successful innovative enterprises adapt to change, according to growing market needs/ requirements and discover opportunities, faster than their competitors. This boosts their ability to overcome challenging situations and helps in retaining the market position and stay ahead of competitors.

The large volume of complex organizational data is challenging to manage. The complexity is beyond imaginable in firms that have been a major player in the engineering and manufacturing industries, ever-present for decades or even centuries in the market. This is because of the traditional methods used to govern data in the age of the digital revolution. The usage and dependence of IT systems helped to manage information and data enabling cross border sharing, exchange, and collaboration. However, data governance is still a major pain point. Many applications have developed into highly dependent systems which are otherwise known as legacy systems. The legacy system continues to be a highly important contributing factor for data governance. During the initial phases of implementation and usage, they had helped organizations manage complex and vast amounts of data. However, over time, the ability of these systems to handle and control the data being secured and governed becomes highly complicated. As a result, various industries were trying to solve the problem cost-effectively and immediately. This further leads to implications like stimulating new legacy systems. Thus, the application or IT landscape of companies became highly complex and unstructured. A similar case is observed in this pre-study as well. One of the core elements of PDM is to minimize the use and dependence of many such data warehouses inside the IS/IT landscape of companies. A PDM system can be seen as a single source of truth where the data associated with the products (individual part, part libraries, and various CAx data) is the core of the system itself. Therefore, the management and governance of the product data are handled in a central data repository, the PDM system.

1.2 COMPANY

ABB Industrial Automation business offers a range of solutions for process and hybrid industries, including industry-specific integrated automation, electrification, and digital solutions, control technologies, software, and advanced services, as well as measurement & analytics, marine, and turbocharging offerings.

Based on the deep domain knowledge, experience, and expertise in delivering world-class automation products, systems, and solutions, a wide area of complementing digital and collaborative solutions across applications and sectors, the Industrial automation business helps customers remain competitive, improving their ROI and running safe and productive operations.

A complete portfolio of automation solutions brings increased quality, accuracy, and precision to industrial processes ranging from the simplest to the most complex.

Regarding the recent management decision towards OpenText implementation, a PLM solution may potentially still be needed to proceed with OpenText implementation, as some crucial capabilities may not be well supported in the OpenText environment; as OpenText implementation assumes a PLM source.

ABB ABILITY™

ABB has been a pioneering technology leader in the digital world, whether on-premise or remotely. ABB Ability brings together digital offerings as one unified offer.

ABB Ability™ combines deep domain expertise with unmatched experience in connectivity to enable customers to know more, do more, do better, together. Deep domain expertise – Insights across multiple industries with more than 40 years of experience in digital technology – Global leadership in industrial process and automation knowledge. Being a leader in control systems with unmatched connectivity experience, the company has an installed base of 70m digitally enabled devices, 70,000 digital control systems, and 6,000 enterprise software solutions. It is also a world leader in securing and using data. The customer benefits include a device to enterprise-level transparency into operations. The control room is a flagship product of Industrial Automation. A typical control room is depicted in Figure 1.

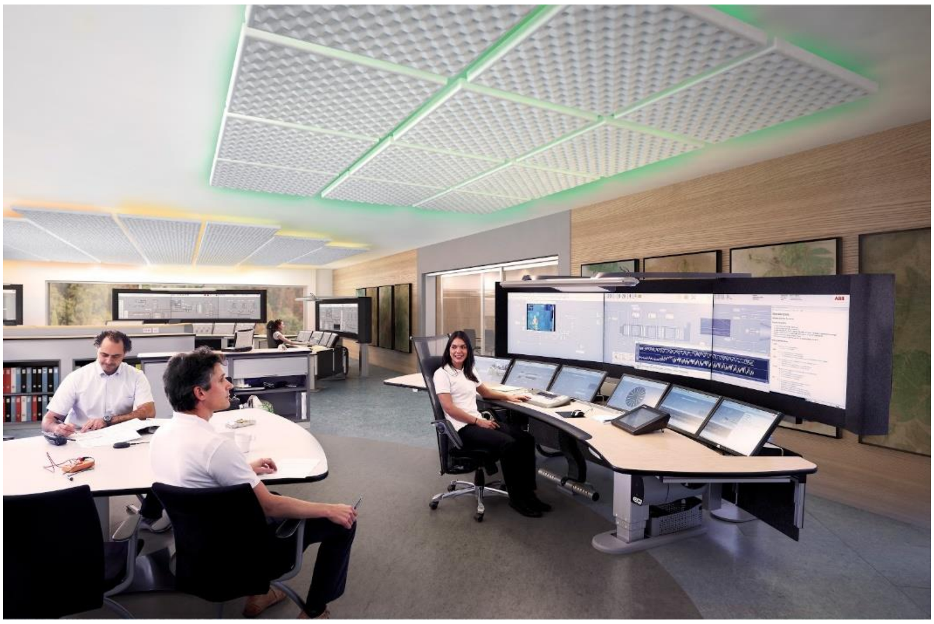

Figure 1. A typical control room, a flagship product of Industrial Automation

1.3 PRODUCT NEED

To continue the ABB Industrial Automation business legacy, especially in the area of Product Development and customer satisfaction, there is a growing necessity to keep pace with digital transformation trends. Digital transformation not only paves the way to achieve a completely data-driven business model but also to harmoniously carry out increasingly complex business while driving innovation. Rapid changes in customer demands must be addressed swiftly to sustain in the global market. This requires that the internal data and information governance are of the highest standards. To achieve this, the finest and 'top of the range' technological advancements need to be incorporated inside the existing business models. In relation to our work, we articulate that a proper PLM philosophy and backbone PLM system within the bounds of ABB IA unit, will enable to achieve improvements in the way business is conducted as well as establish control over the internal processes to be a market leader, continuously satisfying the customers

1.4 Project Objective

The project aims to conduct a detailed investigation for a feasibility study of why PLM needs to be introduced at the IA Business unit. This is followed by gathering requirements for the new structure, synthesizing a layout and implementation plan for the desired system architecture that needs to be integrated into the existing architecture of the organization, considering the harmony of organizational behavior. The project also aims at conducting a benchmarking study to investigate if there are any similar solutions already existing within the company as well as studying the market to establish a standard. Finally, the project concludes with a business case model estimating the cost of investment and the Return of Investments (R.o.I) and other standards and associated considerations.

1.5 Scope

Adhering to the project timeline and considering the realistic goals which could be achieved during this pre-study, some major considerations regarding the scope of this project were defined. Setting a realistic scope for any PLM project requires a deep understanding of organizational mentality as well as common objectives inside the Business Unit. By conducting regular interviews, meetings, and discussions with various stakeholders involved, the scope was outlined. A major part of the work focuses on laying a strategy for PLM introduction, vendor comparison, and entailing the best practices to this date.

1.6 PLM initiative

In the context of this project, certain objectives have been outlined as part of the initiative. These objectives are framed as part of the bigger picture of PLM philosophy within the organization. The activities and scope of this pre-study constitute a significant part of this long-term vision. These could be described as follows:

1. Products form the basis of organizational revenue and business.

2. Various product data related to each product constitute the basis of products.

3. Product data, therefore, is seen as the most essential and valuable commodity for the organization.

4. Managing product data responsibly and carefully is essential for the smooth functioning of the organization.

5. Successfully managing the product data from the ideation phase to end of life directly contributes to improved time to market, innovation capacity, and new product development.

It is important to note that various companies start the PLM initiative due to different reasons related to distinct needs and organizational goals (Stark, 2018). However certain similarities could be observed as part of the initiative. As stated by (Wuest & Wellsandt, 2016) due to the emergence of PLM in PDM and CAD, conventional PLM aligns with the first phase of the product lifecycle. The traditional views have been evolving due to emerging needs and research. (Jun, Kiritsis, & Xirouchakis, 2007) discuss the closed-loop

PLM concept, that it better emphasizes managing and tracking entire product lifecycle information including information to product lifecycle phase as possible feedback.

In the context of a paradigm shift in PLM, (Stark, 2018) mentions that a paradigm shift happens through everyday experience when most people realize that the existing situation no longer fits the practical reality of the domain. As a result, (Stark, 2018) reveals that the paradigm for the domain changes as things change over time.

The concept of product data didn't exist in the previous paradigms as the data belonged to different departments such as Engineering, Manufacturing, and After-sales to name a few (Stark, 2018). With the growing realization of PLM, (Stark, 2018) mentions that product data seemingly gained value and is intellectual property as well as a corporate strategic asset, with security procedures for product data protection. These realizations helped create more organizational value for product data. With the emergence of PLM, (Stark, 2018) refers that the management can be seen transforming into a holistic and collaborative approach from the previously separated and divided approach, as products, applications, people & equipment, business processes, and applications are holistically addressed in PLM.

According to (Stark, 2018) regarding the operational benefits of PLM, the following points are worthy to be noted.

1. Transparency regarding the product life cycle is provided by PLM.
2. PLM provides visibility to executives related to what's happening with the products.
3. PLM provides visibility over Product Development, modification, and project retirement.
4. PLM diminishes conflict related to product information.
5. Access to the right information aids in better decision making and this can be achieved through PLM.

Further, (Chiabert, Bouras, Noël, & Ríos, 2018) add some other criteria with respect to the above topic. These are as follows:

1. PLM approach is such that processes are just as important as data.
2. Thus, when dealing with PLM implementations, the design process is the fundamental backbone to define processes and associated workflows.
3. Therefore, for a successful PLM environment, it is necessary to structure the supported methodologies.
4. The backbone of the innovation process and early design stages is the design process.

1.7 Research Questions

During the project, there have been a lot of suggestions and ideas as to how this pre-study would bring value to the IA business unit. Interviewing with numerous Master Data Managers and ERP users, it was clear that different entities inside the organization - individuals and groups, faced distinct problems due to the current application landscape as well as with certain distinct applications. This again proved that the research questions, needed to be grounded to bring in the commonalities between various questions different stakeholders have, at the same time create value in terms of business and turn return value to the employees and the organization IA. The corporate questions of this research include:

- Why is PLM the need of the hour at IA?
- How would PLM bring value to the ABB business line?
- How can we integrate PLM into the existing IS landscape?
- How to connect clustered silos of data (people, processes, tools, and products) within ABB IA to lead digitalization?

1.8 Delimitations

This pre-study concentrates and focuses on the aspect of understanding the business benefits of introducing a PLM backbone for ABB Industrial Automation. The associated studies which are part of the scope include current organizational strategies and techniques of sharing product data. Dedicated aspects of this pre-study include framing the existing means of governing Product and Material master data. This is partly because the stakeholders who played a crucial role in defining the pre-study were majorly involved in the Enterprise Resource Planning and management domain. A large volume of data exchanged and governed by the domain with other domains, i.e., Research and Development, Quality, Supply Chain and Information Services, indicated that a PLM foundation is necessary to maintain credibility for governing product data, which is the core of the business as it directly relates to the products. Due to high amounts of complex product data, it proved to be essential that a secure Product Data Management system needs to be in place.

The aspects of research that are not covered in this study include the possibility to develop an in-house PLM system. This is partly due to the complexity and high amount of resources needed to make it a reality. Also, this study specifically addresses the PLM introduction at the ABB IA business unit and not at a divisional level. This is because IA on its own has a very complex data flow, and as a first step, it was necessary to focus on a local level, concentrating on the research questions. Also, reducing the complexity of data flow between different systems (applications, databases) could be achieved by reducing the no of software or applications, by introducing a central PDM system. Doing so, it not only assures that the technology adoption and data governance is in line with global industrial standards for business growth but also to aid the unit in effectively using the available resources, thus reducing time to market, being lean, and dedicating more time for product innovation.

Other topics, which are not covered in this research include Application Lifecycle Management (ALM). The IA business line being the world leader in Control Systems, which is a very complex product with more than 10,000 individual parts in some cases. A huge amount of software suites constitutes a major part of the product. Therefore, it is also necessary to understand the role of ALM and cyber-physical systems in the context of product offerings related to PLM.

- ALM is not covered.
- The study is focused only on PLM pre-study inside ABB IA.
- The possibility of developing an in-house PLM is not investigated.

(Bertino & Hartman, 2015) present some of the major cybersecurity risks. These are as follows:

- Attacks against mobile devices
- Attacks against embedded devices
- Attacks against critical infrastructures
- Insider Violations and Threat, and Data Exfiltration
- Compromises in the cloud
- Large-scale attacks
- Cyberwars

However, (Bertino & Hartman, 2015) provide crucial elements of PLM related cybersecurity by providing a research roadmap and questions which need to be addressed. An interesting discussion by (Bertino & Hartman, 2015) under cloud security and the use of the cloud for security include that different security measures need to be taken depending on how the cloud is incorporated. E.g.: as backend storage or as a platform for global collaboration.

2 Methodology and Research Framework

This pre-study was carried out mainly through qualitative data collection expert interviews, stakeholder analysis, observation studies, and literature review constitute the research methodology throughout this pre-study.

During the data evaluation and analysis phases, quantitative data is gathered from the collected data. Certain quality criteria for quantitative research are reliability, replication, and validity. Finally, the data gathered from the literature review and inhouse interviews are combined to suggest improvements regarding the previously quantified data to improve the performance metrics in line with PLM implementation.

2.1 Business research

According to authors (Bryman & Bell, 2011), the postulate that the social investigation approaches with regards to qualitative and quantitative research are different and crucial ontological and epistemological considerations are carried with them.

This study can be methodologically addressed as a subset of Business research. (Bryman & Bell, 2011) address the quality of business research by the reliability, replication, and validity of the work as a key criterion.

2.2 Expert interviews

One of the most effective ways to conduct different arrays of business research that need cooperation from the active stakeholders involved is through conducting expert interviews. In this pre-study, the most effective benchmarking and requirements gathering were carried out through a set of prescribed expert interviews with domain experts.

Most of the interviews aided in establishing a ground for research with different suggestions and expert opinions about the subject in general, but also kept the research grounded to the scope and expected outcomes.

During the interview sessions, it was crucial to respect the time the interviewee has dedicated to this project, thus preparing beforehand seemed necessary. According to (Bryman & Bell, 2011), before conducting an interview, it is crucial to gain general knowledge about the subject and explain the format, purpose, and confidentiality. In the context of this research, most of the interviewees had little knowledge about the study, as it was previously communicated through emails or telephonic conversations. This not only helped save time during the actual session but also contributed to understanding more about other associated facets of the study.

Exactly as interpreted by (Bryman & Bell, 2011) it was observed that Expert interviews provided a better understanding of the subject, which also helped in realizing new perspectives and opportunities, which constitute a differentiating factor compared to other methods.

2.3 Emails

Throughout the data, collection process emails were extensively used to collect and share data. This was a convenient way for employees to share data securely as well as providing comfort in expressing their thoughts and sharing data. It also has more anonymity compared to face-to-face interviews and provides an opportunity to check the contents before it is being shared.

Other strengths include (Bryman & Bell, 2011) the possibility for continuing a detailed discussion with follow-up questions at the same time giving the respondents more time for analyzing the questions and answers.

(Bryman & Bell, 2011) also showcase the downside of interviews that it is impossible to evaluate the respondents' reactions and expressions, whereas in some cases the emails could also be viewed as spam.

2.4 Literature review

The other most effective way to gather background qualitative knowledge on the topic at hand is to conduct a literature review of scientific journals, articles, and other related research conducted on the same topic both within and other organizations. This enables us to gain in-depth knowledge of how to approach and proceed with the study. Further, it helps in narrowing down the field of wide-area study while providing empirical evidence of the frameworks and processes that need to be addressed while conducting the research (Bryman & Bell, 2011).

2.5 Framework

The entire project was carried out in the Six Sigma framework following the DMAIC framework.

Figure 2. elements of the DMAIC framework

Define, Measure, and Analysis phases were mostly considered. A visual mapping of the DMAIC framework is represented in Figure 2. This pre-study focuses on the scope, wherein the outcomes of the project are in terms of recommendations and findings from the research questions. Considering these factors, the first three stages of the DMAIC framework were most appropriate. Certain observations regarding the 'Improve' phase were noticed, however, the major focus was to iteratively refine the project in terms of Define, Measure, and Analysis'. Capturing the existing knowledge was crucial to establish the necessity of this pre-study. By conducting cross-domain expert interviews, it was possible to frame the plot for this project by capturing and synthesizing requirements.

3 RELATED WORK

Various topics such as the need for Product Lifecycle Management implementation in corporate multinational firms, implementation perspectives in the complex and highly demanding Product Development landscape, PLM architecture in mechatronic product development, Product Information modeling, and introducing PLM in existing IS/IT landscape were studied and analyzed in detail.

The other topics related to the literature review include:

1. Enterprise architecture
2. Importance of Requirements Management during PLM implementation projects
3. PLM in the context of industry 4.0
4. PLM in Cyber-physical products

A detailed view of PLM considering the internal composition is better explained by (Lee, Choi, Kim, & Noh, 2011) composing three axes, which are as follows:

1. Intelligent Design System: associated with the origin of products, processes, and resource information.
2. PDM: responsible for the systematic integration and management of products, processes, and resource information.
3. Digital Virtual Manufacturing System.

Some major studies and observations which were used as a reference during the pre-study are explained in the upcoming section.

3.1 Product Data Management (PDM)

Excerpted from (Zimmerman, 2008) Product Data Management systems can be seen at the foundation of Information System Architecture. A PDM system provides the capacity to store, browse, exchange, and collaborate information and data regarding the products. It also provides a link to ERP systems through integration.

Product Data Management serves as a central knowledge base for data exchange between various domains and users who connect with the products. A PDM system can generate reports related to the product. A PDM system also serves as the central system or database for initiating various activities like engineering change management, product information revisions, establish control over different variants and revisions of different parts, manage the Bill of Materials and provide extended support such as configuration management.

The data created in the PDM systems can be used downstream to other applications such as Enterprise Resource Planning suites to monitor the transactional process of the organization. Thus, the core data created and managed in PDM is used throughout the lifecycle process and of the product and the organization's business such as Sales, Supply chain, and entire revenue stream.

3.2 Product Information Modeling (PIM)

From the description by (Sääksvuori & Immonen, 2008), the concept model that analyses information of the product and its relationship with other bits of information by formal and careful description is defined as the Product information (data) model.

Adding to the above description, (Sääksvuori & Immonen, 2008) also provide the following descriptions:

1. In the Product information (data) model, the product information, and the relation between different bits of information are described only at a conceptual level.

2. The whole concept of this model is to describe the concept of a product.

3. The function of the product information model is as follows: scrutinize the product on a general level, to examine the product's common properties and forms of information thereby forming the product's generic information data model which is appropriate for each case at a general level.

According to (Sääksvuori & Immonen, 2008) the key function of the model is to represent the necessary information and the importance of a product point of view.

(Bergsjö, Malmqvist, & Ström, 2006) conclude from their research investigating the extent to which PLM systems available during that time can manage mechatronic product development that the principles of an integrated information model are not affected by the complex products produced by small and large companies. Their study also points out the necessity for a better and detailed information model in large companies due to the existence of advanced formal procedures.

Regarding the well-known issues in implementation, certain commonalities can be observed. (Bokinge, 2012) concludes from his conceptual framework chapter that the PLM concept is not clearly understood, and many times creates contradictions. Also, (Bokinge, 2012) observes that such endeavors require dedicated interest from the stakeholders and continuous support, and it is also worthy to note that understanding of enterprise software and people’s progressive mentality to change is essential. Therefore, for establishing success, some hurdles need to be overcome regarding changing the political landscape and organizational changes.

A general trend being observed is that irregular PLM implementations are performed in many case-studies. This is partly associated with the fact that due tothe addition of new team members in every project, captured knowledge is not fully utilized and reused.

3.3 Configuration Management

(Bergsjö, Vielhaber, Malvius, Burr, & Malmqvist, 2007) convey that special challenges are observed in cross-x engineering environment regarding the management of both versions and variants of product information. Due to the necessity to manage a huge amount of both people and components, the process is complex in a single-domain environment as well.

In a multi-domain environment, differences in the product development process between different engineering disciplines are problematic – for example in software and electronics development, different life cycles, prototyping mechanisms, configuration logics, and data schemes are used than in mechanical development.

This process secures that product configurations and project documentation are transparent and traceable at any time during the engineering process of a complex system.

As an engineering management process, the engineering process of a complex system including transparency and traceability of product configurations and project documentatios at any time is secured by CM (Müller, 2013). It is also mentioned by (Müller, 2013) that controlling the variance of the product and its engineering data is highly relevant for this type of Configuration Management.

3.4 Change Management

According to (Barnard & Stoll, 2010) in the present climate of evolving political priorities and economic pressure, organizational change has become a priority within most organizations. However, organizational change is a highly complex process, which can have varying outcomse for the organization.

Change Management in this context can be seen as a continuous process that buds from the PLM concept and continues through various phases like the development of the concept, deployment to the operations phase. It is a continuous process of engaging in transformative practices. Change Management supports the process of Engineering Change Requests (ECR) and Engineering Change Notice (ECN) fostering accurate and collaborative decisions. With a PLM, the process of Change Management is constructive with standard protocols for changes regarding product version management. This one aspect has been lacking in the current landscape due to the limitation in the types of systems handling this process.

(Müller, 2013) mentions that the method of interlinking CM processes with requirements engineering, project managemen,t and generic development process is defined as Engineering Change Management (ECM).

3.5 Standards

STEP is a neutral standard defined by ISO. It can be viewed as a basic standard for the exchange of PLM data. Dealing with product data exchange, ISO 10303 is a subset of STEP. (Zimmerman, 2008) mentions that ISO 10303 offers methods to facilitate data exchange between systems, by structuring information. (Zimmerman, 2008) also describes that STEP methodology implementation would allow the companies' freedom of action to engage new information systems and reduce the complexity in later system integration. (Zimmerman, 2008) also, suggest that utilizing STEP constructs can be utilized to enable data import/ export features.

(Pratt, 2001) present that the implementable parts of ISO 10303 are defined as Application Protocols (APs). According to (Pratt, 2001) APs can be defined as the translators-based parts defining models. (Pratt,

2001) also describes that a set of Integrated Resources (IRs) constitutes APs. According to (Lubell, 1996) IntegratedrResourcse are the reusable components for building APs, specified by STEP standard.

According to (Kadiri & Kiritsis, 2015) some of the most widely used APs are AP203, AP21,4 and AP239 whose major focus is product data management and geometry information. (Kadiri & Kiritsis, 2015) specify that these AP does not constitute the beyond geometry information representation regarding a product.

As a result, the Core Product Model (Fenves, 2001) was developed to address this issue (Kadiri & Kiritsis, 2015).

According to (Sudarsan, Fenves, Sriram, & Wang, 2005) the Core Product Model (Fenves, 2001)cano capture detailed and comprehensive engineering data associatedwitho product development.

An extension of CPM, called the Open Assembly Model (OAM), was then creater to include assembly representation (Rachuri et al. 2005). A unified view of these two-information model's CPM and OAM has been implemented as a basis of a product information-modlling integration framework for PLM.

The representation of beyond-geometry information such as the function and behavior of the product is usually not part of the information contained in these AP.

3.6 PLM maturity models

(Chiabert et al., 2018) extracted PLM maturity models from a systematic literature review. They are as follows:

- Batenburg Proposal
- Saaksvuori and Immonen Proposal
- Schuh et al
- Stark Proposal
- Kärkkäinen et al. Proposal
- Terzi S.

These models define various methodologies and frameworks for the assessment of PLM maturity.

To be more precise, the models represent PLM achievements, stages of maturity concerning life cycle management, maturity elements of PLM, maturity model for PLM, assessment of organizational maturit,y and assessment model for New Product Development.

Another recent development maturity model represented as collaborators from various European enterprises and R&D institutions by (Chiabert et al., 2018) is RAMI 4.0 (Schweichhart, 2016) or the Reference Architectural Model for Industrie 4.0. The original model is visually depicted in Figure 3. The model represents the right approach towards Industrie 4.0 through a 3D map in a structured view.

According to (Chiabert et al., 2018) the 3 quadrants of the RAMI 4.0 maturity model represents the topology levels of a manufacturing system through the internet, different lifecycle systems and the IT structure of a component in Industrie 4.0

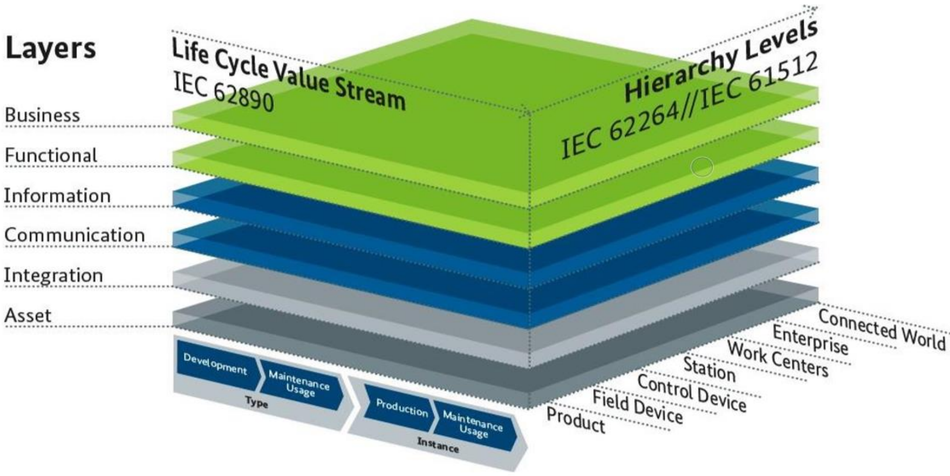

Figure 3. RAMI 4.0 – The Reference Architectural Model for Industrie 4.0

(Vezzetti, Violante, & Marcolin, 2013) conclude from a detailed benchmarking study on the above-mentioned maturity models thatthe Batenburg model and Terzi model prove to be the most complete, from every angle. The criteria used for benchmarking by (Vezzetti et al., 2013) includ: Detail level, Testing, Effectiveness, Applicatio,n and Addressed domain. The benchmarking results are presented in Appendix B.

4 Findings

In this section, the major findings of the pre-study are briefed.

4.1 Captured Requirements

(Bokinge, 2012) implies from a real-life case-study that considerations regarding the existing situations of different business divisions/domains need to prioritize during an effort to implement a common PLM system. Considering the number of organizational resources dedicated to this project, it was vital to understand the requirements related to Data Management from various domains within the business unit. Although most of the requirements gathering in this project were from the Master Data domain, other divisions such as R&D, Sales & Marketing, etc. were also addressed. Most of the requirements were gathered through conducting interviews with personnel from different aspects of work within the organization.

It is validated from this pre-study and as put forward by (Bokinge, 2012) considering PLM implementations, the role and impact of requirements management are multifaceted. Despite each division having many unique needs, many of the needs when translated were common pain points throughout the organization. Microsoft Excel is one of the most popular tools that is used in various divisions for data management. Although MS Excel is a versatile tool, it did have some major drawbacks that came to light during the investigation. Product data could be updated, changed or removed by anyone who had access to these systems, this posed as a threat as the system did not record the history log of who did the change, in other words, the data was prone to tampering e.g. an employee in Product data management shared that the attributes of the products could notbe kept universal as there were data managers around the world had access to the master system that maintained the product data, which would confuen. This unprotected data also leads to data duplication, as the same product had different sets of attributes in different systems. Further, the factor which affected the data duplication was that each division inside ABB used different platforms to store and manage data such as database1, database2, application1, application2 and so on which is been represented in figure 4. It was notable that the synchronization between these systems was insufficient and, in some cases, almost negligible. Among these many systems, some of them were legacy systems that have grownovern the course of time which had become a considerable issue.

It is significant to realize the challenges posed because of such legacy systems. To provide a detailed view, certain key challenges of legacy systems as proposed by (Srinivas, Ramakrishna, Rao, & Babu, 2016) are presented, which are as follows:

- Legacy systems operate slow, are expensive to maintain and outdated.
- Integration with different systems posse a challenge due t ao lack of specific interfaces.
- Fault detection is often tim- consuming and expensive, making it expensive to maintain.
- Provision to provide new functionalities as required by the organization is almost impossible.

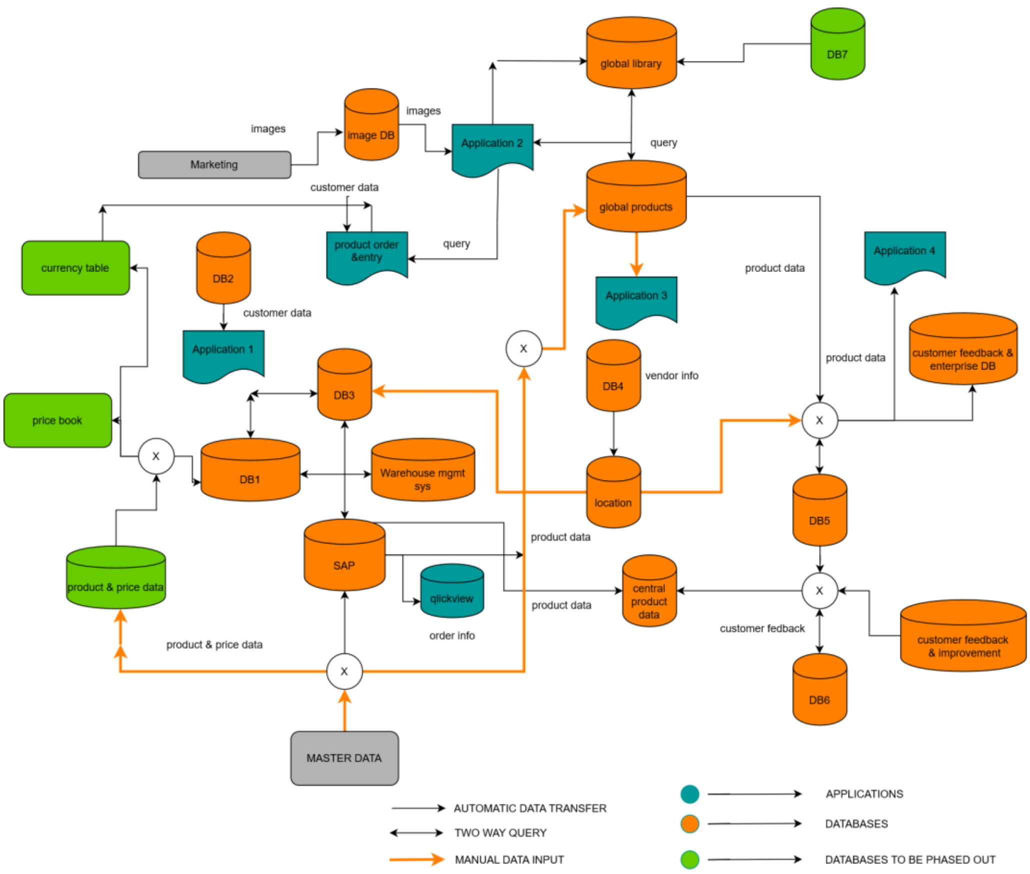

Figure 4. Current application landscape within Industrial Automation

One of the flagship products of Industrial Automatio, comprises more than 10,000 parts, which naturally pose as a challenge to manage and maintain the amount of data and other involved processes for every single part. During the interviews employees from various sectors of the organization, claimed that the part management system is complicated and complex. In addition, the ability to trace the product's version was found to be inadequate. Further, the system that is used to handle the product data revision and updating eres also found to have room for improvement. The bill of material (BOM) generated for each part is commonly generated in house, however, in certain scenarios, an external vendor controls the generation of the BOMs' and each cost associated with change request are seen to be costly and very high time involved.

ABB operates in more than 100 countries, which means that each division of the organization has multiple branches that are spread across the globe. With each division spread geographically a Central Source for product data is required for the divisions to operate without any complexion. Through the study, it was brought to light that a central source for data related to the product on a global level could be improved that can improve global sharing, collaboration & template reuse of configurations and quotations. It was also evident that a standard tool for end-to-end sales processes could be incorporated to increase operational efficiency and productivity on the Global level and could also improve sales that have a more transparent process which is shortfall within the organization. To generate a new product configuration and in the current scenario has high efforts and low quality due to high manual intervention between sales processes and tools as reuse of configuration and quotes is a difficult process.

Capturing the requirements from various departments uncovered a lot of similarities which were previously scattered within the division where this project was held. Table 1 represents the commonalities, mainly the pain points. These were synthesized as requirements answering the research question about the needforf a PDM/PLM system for ABB IA, Business Unit X. Among the captured set of requirements, some of them were addressed individually by all the departments which were the datasets, i.e. R&D, MDM, I,S and Sales and Marketing. From the data collectio,n it was observed that data duplication was addressed as a critical phenomenon by all the above-mentioned parties. To some extent, controlling data duplication would avoid other implications such as scattered data ownership and poor data protection.

Table 1: Similarities of requirements between departments

	R&D	MDM	IS	SALES & MARKETING
MARKET LEADTIME	✓	✓	✓	✓
PART MANAGEMENT COMPLEXITY	✓	✓	✓	✓
DATA DUPLICATION	✓	✓	✓	✓
MANY SYSTEM, LOW SYNC	✓	✓	✓	✓
MINIMAL PRODUCT REVISION HANDLING	✓	✓	✓	✓
IMPROVEMENT IN DATA PROTECION	✓	✓	✓	✓
DATA OWNERSHIP NEED IMPOVEMENT	✓	✓	✓	✓
DATA LOG NEEDS REGISTORY	✓	✓		✓
COMPLE COMPONENT TRACEABLILTY	✓	✓		✓
PRODUCT DATA MANAGED IN MS OFFICE	✓	✓		✓
DATA SHARED VIA E-MAIL	✓	✓		
BOM GENERATED EXTERNALLY	✓			✓
COMPLEX TRACEABLITY FOR WORKFLOW	✓	✓		
OVER PRICE BOM GENERATION	✓			
QUOTING QUALITY NEEDS ENHANCEMENT	✓			✓
LACK OF GLOBAL END-TO-END SALES PROCESS	✓			✓
REUSE OF QUOTES IS REQUIRED	✓			
ERP HAS MANY LEGACY SYSTEMS		✓	✓	
LESS SALES TRANSPARENCY			✓	✓
CENTRAL SOURCE OF PRICEING IS REQUIRED				✓

An investment in a backbone PLM system would also help in eradicating many other fuzzy data management platforms. As mentioned in section 4.1, legacy systems pose major challenges. PLM investment brings value by not only acting as a foundation for data governance but also in eliminating many of the legacy systems over time.The eEfficient use of ERs could be a solution to this problem as well. But, the strong business interest to invest in a new PLM solution cancels out this option. A PLM investment was observed as a trend among higher management during this project. Even though all the requirements addressed in Table 1, cannot be fulfilled by a PLM investment, qualitative reasoning through interviews and consulting expertise proved that a PLM investment would bring immense value for ABB IA Business Unit X.

5 Proposed solution

With advancements in the area of Product Lifecycle Management over the past few decades, the PLM global market is more popular now than ever. One of the major capabilities of a PDM system is that it is constructed on certain strucurted fundamentals of product data handling and designed based on standards. Processes such as change management, change Administratio,n and change promotion to name a few, constitute data governance. A simplified view of change promotion process in an industr-leading PLM software is depicted in figure 5, as an example. When breaking down the requirements to map against the expected outcome, the TO-BE solution should have such structured processes.

Figure 5 : Typical steps involved in Business Administrative Change Promotion Process (Windchill).

5.1 Vendor Analysis

From the literature study by (Westermann, Bonnet, & McAfee, 2012) it is pointed out that digital maturity is a combination of digital intensity and transformation management, the former addressing the measure to which technology-enabled initiatives undertaken meant to change how the company operates and the latter referring to the investment intensity in the leadership capabilities required to generate organizational digital transformation.

It is interesting to note that a multitude of new players has emerged in the PLM sphere, offering robust solutions to customers in varying and diverse industries. Therefore, in the context of this study, some promising PLM offerings were studied in detail. The major factors that were considered during the vendor selection phase are as follows:

- The first and foremost factor that plays a key role in the selection of a vendor is the Price of the product (cost factor) that the vendors are offering. The cost analysis covers all aspects of the initial implementation and the year-on-year maintenance & service cost of the new product.
- Secondly, the Performance history of the vendor contributes a vital factor for the selection criteria, this also helps in estimating how credible and successful the offered products are. This also gives a better insight into the technical capabilities that the vendor possesses while understanding the warranty & claim policies of the vendor and the services provided after-sales.
- Finally, the most crucial attribute and the deciding factor that aids in triangulating on the optimal choice for the vendor is the ability to deliver a tailor-made solution that is compatible with the complex business structure of the organization. Further, considering the quality of the delivered solution and the capability of that solution to scale up the product within the organization until its last user. Also, it depends on how soon the implementation can be brought to the "go-live" phase from the initial phasethat must be investigated in detail to increase the value of the vendor.

5.2 Vendor selection

After tedious filtering, the available PLM vendors in the market there were some vendors considered for during this project. These vendors have been analyzed according to the various aspects mentioned in chapter 5.1. Apart from the vendor selection process mentioned in section 5.1, other criteria were as follows:

1. Due to the project timeline, considering all the global PDM/PLM solutions was found to be ineffective. Thus, rounding off on the best available ones with respect to time and available resources were given top priority.

2. Most of the selected vendors had a track record of satisfied customers. The size of the organization where such an implementation was required meant that the prospective vendor needed to possess enough resources and support for the implementation, as well as after the implementation.
3. A tTrack record of satisfied customer stories ase taken into account.
4. The rRequirement to immediately implement with a lean timeline.
5. ABB, being a multinational corporation has several divisions and mostof the divisions had knowledge and experience with different PDM/PLM solutiosn. A few divisions were/ are satisfied with some vendors and this experience was shared between divisions. Therefore, some of the vendors selected reflected on iner-divisional experience and satisfaction which rose from these investments.

The 4 vendors are as follows:

- PDM1 – Solution provided by an American software and services company, with over one million global users for their PLM software.

- PDM2 – French software company which provides one of the industiesy leading PDM/PLM solution as part of a business experience platform.

- PDM3 – Organization focusing on product data sharing software and collaborative solutions.A mMajor presence in Europe and North America.

- PDM4 –a Swedish company with a tailo- made PDM/ PLM offeringtcath is provided according to a company's demands.The sSolution consists of different offerings in a module form, which can be matched to specific organizational demands.

Amongst these above-suggested vendors, PDM1 and PDM2 were 2 marke- leading companies. Engaging with front-line vendor, supports a company in avoiding some of the costs associated with the introduction of new PLM applications.

These companies had a well-established market value and impeccable performance history. On the other hand, the remaining two companies PDM3 and PDM4 have an impressive track recordde spitf being small players on the market. Companies, PDM,3 and PDM4 offered the most customizable solution which was in line with ABB's requirements and had a rather comparatively quicker implementation time, but the customizability and a shorter timeline came with a high price tag in case of PDM4. When evaluating the applicability of PLM software, it is crucial to define the business needs in advance. (Chuang & Chen, 2009) suggest that it is important to pre-define the business needs when evaluating PLM software applicability.

As the companies, PDM3 and PDM4 failed to get past the price factor which was one of the major factors for vendor selection, meant that the only other options were between PDM1 and PDM2. One of ABB's market competitors was considered as they had their own in-house PLM solution (PDM5). However, it was mentioned to us from the beginning that PDM5 need not be considered because it belonged to a major competitor. When further analyzed, the decision was from higher managemen,t and governing the company data in a competitor's product was uncomfortable to ABB IA division X. Another reason was that PDM5 had a heavy price tag. A cost comparison was performed as shown in figure 6, which helped narrow down the to the most suitable vendor that can provide the most optimal solution needed. PDM3 and PDM4 were eliminated in cost analysis.Beforeo the cost analysis, it was suggested by the management to omit them from the cost analysis. From the preliminary cost analysis, it was evident that PDM1 was the best option. Although in this context Return on Investment could not be given in actual value, it is noted that implementation of a PLM system benefits the organization in terms of cutting down in cost in various processes such as reduced time for data search, improved employee productivity, reduction of errors which is shown in figure .

Contacting major vendors from our side seemed oto tedious and many of the multinational vendors, with huge market shar,e seemed to be difficult. Our observation and analysis are that it might have been because, even though we were part of ABB during the project, these vendors were interested in contacting personnel who had the power and authority to invest in such large-scale projects. Since the investigative case study for a PLM system was ongoingfore a long time, the actual cost figures of PDM1, PDM,2 and PDM5 were readily available with ABB subject matter expertise. But inthe case of PDM3 and PDM4, it was straight forward for us to get the required information as the political landscape within them were flat. Also, the companies appreciated our curiosity and found us as a platform to connect with ABB and engage in business with a multinational conglomerate to increase their market presence.

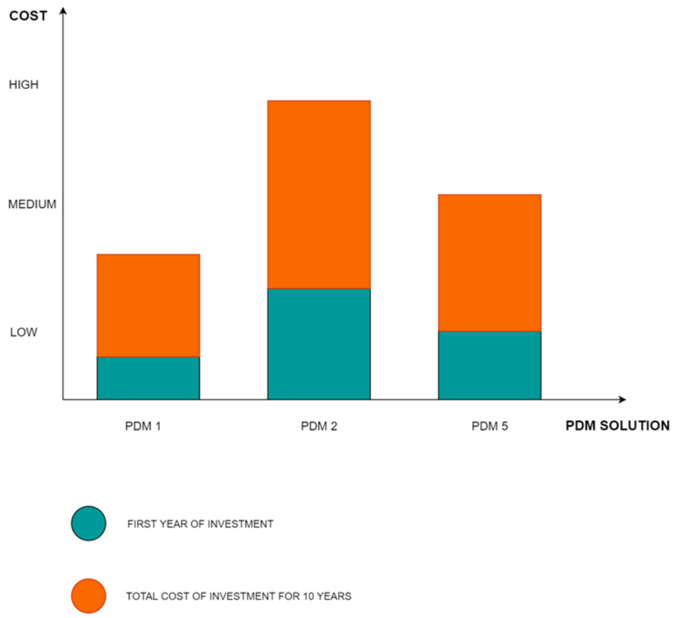

Figure 6. Cost analysis of selected vendors.

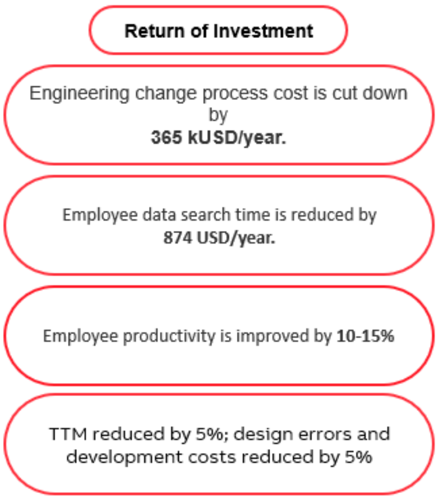

Figure 7. Return on Investments in terms of value.

5.3 Solution offerings

From the cost analysis, it can be established that it is a better investment to incorporate PDM1 atthe IA business line. This was also a wise choice as there were many benefits. One of the major reasons was that PDM1 did not have any installation cosst.

PDM1 offered a highly updated solution & platform with a large array for customization which is required for individual divisions within the organizations which are also interrelated as shown in figure 8. It also had the provision to link different ERP systems which eres one of the key requirements for IA. While windchill offered all the generi features of a PLM system, such as PDM, Project Planning, Document Management, Change Management, Business Integration, Non-CAD integration, BOM/ EBOM Management, Enterprise Change Managemen,t etc., the most attractive feature of PDM1 V 11.0 is Cloud Based PLM system with a large capability to scale up.

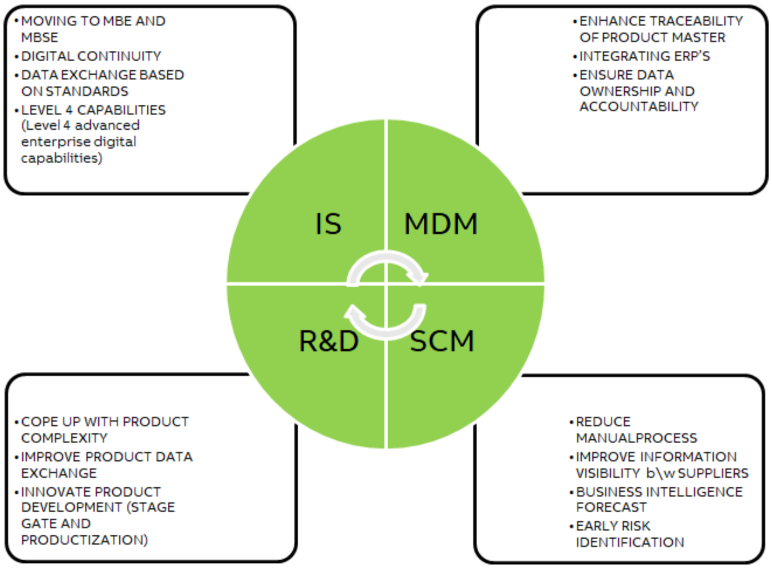

Figure 8: Domain Interrelationship within IA business unit to move towards PLM

5.4 Suggested PLM roadmap

(Batenburg, Helms, & Versendaal, 2006) developed a PLM framework by adopting the concepts of business/IT-alignment as well as capability maturity. It strated by (Batenburg et al., 2006) that carrying out PLM investments must include alignment of various business dimensions, assured by an integrative plan.

Involving various stakeholders from multiple domains makes the process of achieving the desired outcome more tangible from an organizational solution point of view, which is shown ie figure 9.

Regarding stakeholder engagement and corporate responsibility, (Greenwood, 2007) mentions various facets regarding this practice, as mentioned below.

- Throughout the various phases of the roadmap, stakeholder engagemen, seemingly is a crucial attribute.
- The process of stakeholder management can be seen as a set of organizational practices and activities to positively involve the stakeholders.
- Stakeholder engagement is a morally unbiased process as it may support exchange relationships based wholly on rational factors.
- Moral connotations exist in the practice of stakeholder engagement.

- Therefore, the argument is that corporate responsibility and stakeholder engagement are separated but are interrelated.

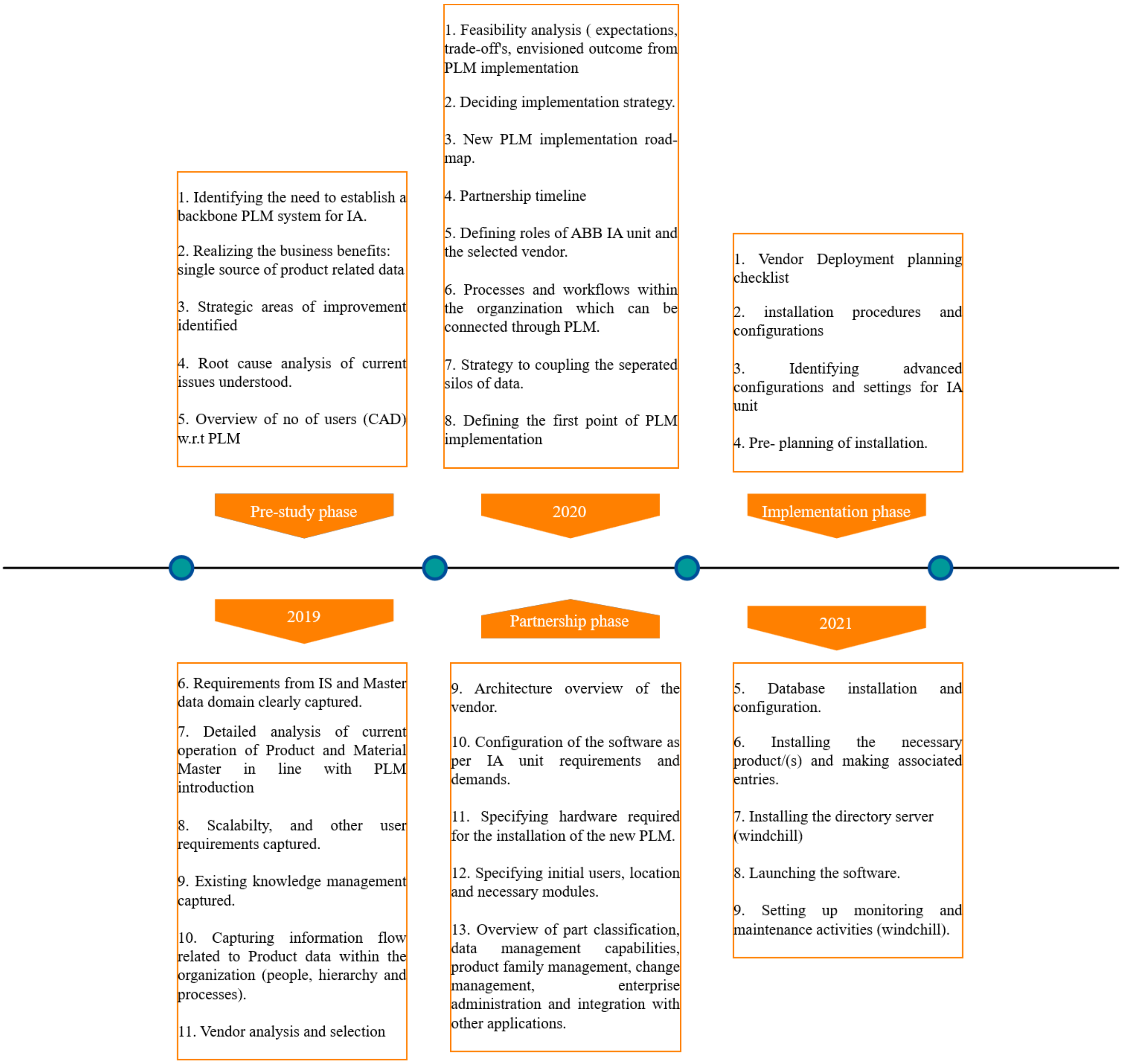

Figure 9. PLM implementation timeline with important activities for IA - a holistic view.

6 Discussion

This PLM pre-study has contributed to various results and knowledge for the IA business line and is expected to support ABB IA in moving forward to invest in a PLM solution. The methodology adopted in this research is directly related to the obtained results of this pre-study.

Qualitative data collection was used as the major method of requirements gathering. This was done through a set of expert interviews, stakeholder analysis, benchmarking to understand the best industrial practices for establishing an effective PLM backbone. The complexity of various products and enterprise architectural landscape of the organization needs to be more effectively understood. A better understanding of the overall operations and the link between various systems (applications, databases, softwar,e and people) is necessary to effectively introduce and use the new PLM system to reap the full benefits from a PLM solution. Also, effective scoping (six sigma) was being used as a starting point for defining the variables and interdependencies of the project mission and scope. Later, it was found to be tim- consuming and could not be condensed into valuable deliverables. Specific tools to carry out digital transformation initiatives with lean methodologies and Six Sigma could help duringthe pre-study phase of such initiatives. Even though such frameworks exist, most of them were found far away from a real-life industrial scenario. In particular, these tools could improve resource utilization by minimizing wastage of available resources.

Also, it is worto noinge that higher corporate management is effectively participating in the proces,s and from various studie,s it is a crucial factor for a successful PLM implementation. At the same time, certain challenges were faced during this pre-study. PLM is a global initiative within the enterprise. A proactive employee understanding of PLM within the company will help in establishing a strong foundational knowledge about the subject and likely increase the readiness to change for a higher meaning. From our perspective, we find that ABB IA Business Unit X is highly interested in best-business practices and is highly complee. Due to this, questioning the ambitions of the higher management decisions did not prove effective at times. The observation, analyse,s and roadmap presented by us were appreciated and considered at all times. However, our limited presence within the organization for a specificperiodn meant that our nature o thef research was considered from a consultant point of view.

In this pre-study, it was also observed that the gap between academic literature and reality inside the organization related to certain theories and findings exists. E.g.: the initiative to find the PLM maturity index inside the organization was found to be a time-consuming process with not so beneficial results in the end. We try to articulate this in an unbiased way from a purely academic background but being a part of ABB IA Business Unit X durinf this project. Therefore, it is observed that there is a necessity to develop more efficient tools and methods to understand the PLM maturity index of organizations. This not only helps in saving time but also to come up with more concrete results for the company before investing in a PLM/PDM backbone.

It is also observed from the literature review and successful PLM implementation projects in industries that a strong understanding of requirements has supported and plays the most crucial part in establishing a PLM foundation. But, understanding requirements is a time-consuming process and more methodologies that will help in speeding up the process will pave the way for focusing on major requirements, but also to be on the right track during the developmental phases of the projects. Academic research regarding requirements management is mostly theoretical and even though certain frameworks exist, they are time-consuming and in industrial contexts don't reflect reality. Another observation was that during this project, the immense amount of help received from the stakeholders within ABB reflects the fact that curiosity regarding the PLM philosophy exists within. However, incorporating real-time Organizational Change Management requires much more than curiosity. This process has to speed up and actively engaging employees in discussions and peer-sharing of new knowledge in line with digital transformation might empower the organizational willingness to change and thus transform.

As mentioned ie chapter 5, PDM 1 was suggested as the final vendor which would be implemented at ABB. It was only during the wind-up phase of our investigation, was it observed that many of the decisions and opinions regarding vendor selection had been already been formed. Although we have discussed many of the criteria for selecting this vendor there was another strong reason which has not been addressed in the previous chapter, the organizational push. Other business units of ABB have already integrated PDM1 into their organizations which was a major constituent as part of the decision making. The benefits or drawbacks of the proposed solution cannot be completely addressed at this point, as it is purely based on theoretical, qualitativ,e and cos- based analyses. It also depends on the extent to which such solutions are dissolved onan individual and departmental level. These types of investments are sometimes motivated due to organizational philosophies and instincts. Also selecting a particular vendor might not be the crucial element. From our observation, it is the ability to adapt to such impactful change,s and willingness to move to new types of working environments and systemsise critical. In this context, an example could be that employees need to make a shift from their comfort legacy systems to new systems such as a PDM. Often at times, moving out of the comfort zone could be challenging. This again relates to the philosophical aspects.

New trends and increasingly popular adoption of digital transformation, Virtual and Augmented Reality, Io,T and blockchain technology help companies in establishing process control and gaining a market edge. However, these technologies are still in the research phase and the future implementation of these technologies, merit,s and demerits are still unclear. When such technologies and ideas are developing at a fast pace, a long term PDM investment comes with business trade-of's.

7 Future work

During the project, it was observed that the PLM implementation initiative was found to be highly prioritized among the major stakeholders involving higher-level management. Also, it is suggested from this work that effective collaboration with IT partner institutions of ABB business linse during the implementation phase can benefit the organization in achieving the goal - a full-fledged Product Lifecycle Management concept with a strong PDM foundation. This pre-study has contributed to adding knowledge through verifiable evidence and comparison with different industrial findings.

However, the lack of awareness of the fruitful benefits of PLM was observed in many domains. This is mainlybecauset certain aspects of the organization find that it is not relevant to their area of work or domain. r breakthrough could happen within the organization if the employees are provided with empirical evidence regarding the vitality of cross-functional involvement in the PLM project, irrespective of their roles or domains, as successful implementation requires active participation and realization of the benefits the organization can have as a whole when there is responsible participation. Also, the presence of multiple numbers of applications and databases needs to be merged into single systems. This would foster in minimizing resource utilization as well as reduce the complexity of data exchange through improved data governance.

Other remarks that are relatable and comparable to those presented by (Bokinge, 2012) as is shown in figure 10 is that certain PLM implementation guidelines lack specification with regards to the rationale and dsn't provide information relating to the consequences if the guidelines are not followed.

In the future, better sharing of inter-divisional experiences regarding similar projects and their key takeaways would help in eradicating similar mistakes as well as reusing the organizational knowledge.

In most of the academic work and company-wide implementations, it was observed that PLM ambitions are high, howeve,r striving for Lean Management through PLM would foster better benefits for the industry. Other determining factors to consider are the roles and dependence of ALM in the context of IA products and to gather the requirements in the context of digital transformation.

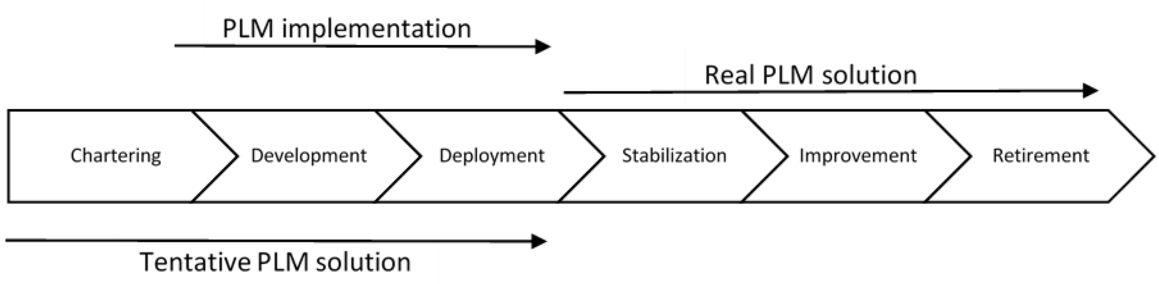

Figure 10: Framing PLM implementation activities - PLM solution life cycle. Adapted from (Bokinge, 2012).

8 Conclusion

From various observations and findings of this pre-study, it could be concluded that the internal quest to find a central repository of product data can in the long term only be made a reality by investing in viable a PLM backbone. Also, from literature and previous PLM implementation study, it is evident that finding the right solution provider is about translating the organizational requirements and mapping with the offerings of the vendor. However, it becomes more complicated at this point to just identify the right vendor. Incorporating a new technology can come with a lot of resistance. Therefore, the organizational mindset to participate is a crucial actor to make the most out of the investment.

In the context of this pre-study, a PLM investment is an important variable in terms of digital transformation for ABB IA, Business Unit X. This is because of the business values which can be incorporated which will directly address the pain points of today. Some of these pain points which translated to benefits are; standardized exchange of data based on high-quality standards such as STEP file format, change request, down streaming data from a central data source (PLM) to the other ERP's at the same time also ensuring data ownership and prevent data duplication.

The suggestion to move forward with the selected vendor is also an indication that apart from the capabilities and offerings, the investment cost and the accompanying business values offered by investing plays a crucial role in PLM implementations.

Finally, the essence of partnership and active engagement of the stakeholders within Industrial Automation, partner institution,s and the selected vendor, would enable IA to achieve in future the full-fledged benefits of digitalization. This will also support in minimizing the existing issues regarding Product Data Management and pave the way to achieve a completely data-driven future.

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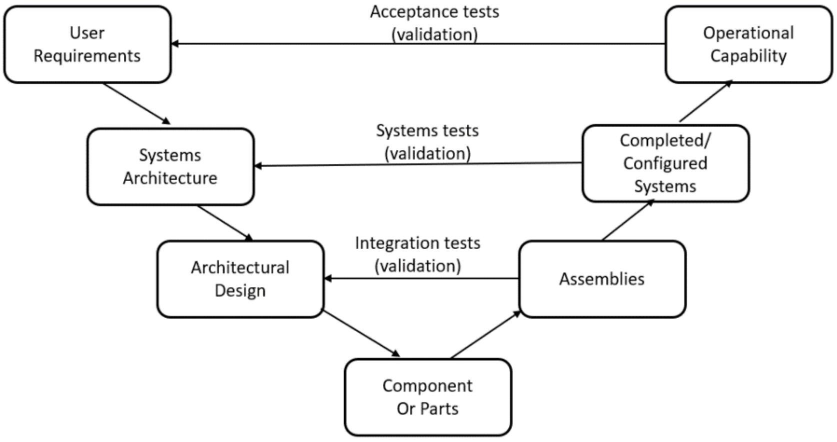
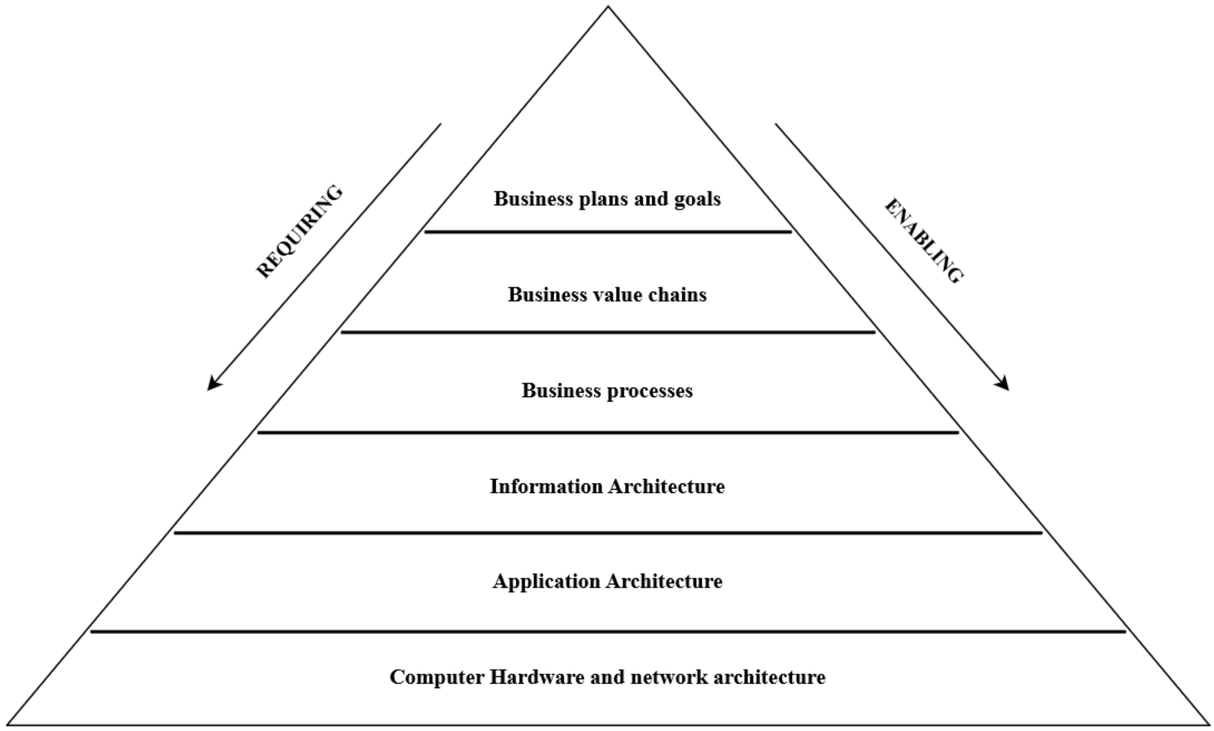
Appendix A - The V-model (Stevens et al., 1998) inspired from (Zimmerman, 2008)



Appendix B - Benchmarking of the PLM maturity models (Vezzetti, Violante, & Marcolin, 2013)

	Batenburg	**Schuh**	**Saaksvuori**	**Stark**	**Kärkkäinen**	**Terzi**
Detail level	1,72	1,11	1,51	1,75	3,33	2,29
Testing	1,87	0,00	0,00	0,00	0,00	2,00
Effectiveness	1,00	0,50	1,50	1,00	0,50	0,50
Application	2,33	1,17	1,17	1,17	1,17	1,67
Addressed domain	0,75	0,75	0,75	0,75	1,00	1,00
Total score	7,67	3,53	4,93	4,67	6,00	7,46

Appendix C - Generic way of describing enterprise architecture (page 21,Zzimmerman)



Appendix D – EFFECTIVE SCOPING A SIX SIGMA TOOL

PROCESS OWNER (ORGANIZATION): ABB AB	PROJECT SPONSOR: INDUSTRIAL AUTOMATION	SIX-SIGMA CHAMPION: LOKESH NANDAKUMAR

EFFECTIVE SCOPING OF CONTINUOUS IMPROVEMENT PROJECTS (PLM PRE-STUDY)

SUPPLIER	INPUT		PROCESS	OUTPUT		CUSTOMER
8B. WHO SUPPLIES THE INPUTS?	8A. WHAT ARE THE INPUTS TO THE SYSTEM?	9. WHAT DOES THE SYSTEM REQUIRE OF THE INPUTS?	7A. TEAM/PROJECT JURISDICTION OF CHANGES	1. WHAT COMES OUT(OF THE PHYSICAL FLOW) - OUTPUT?	3. WHAT IS REQUIRED OF THE OUTPUT FROM THIS PARTICULAR USER?	2. WHO USES THE OUTPUT?
END USERS, DATA MANAGERS	PRODUCT AND MATERIAL DATA DATA FLOW BETWEEN VENDOR AND SUPPLIERS	TEAMWORK AND PARTICIPATION, KNOWLEDGE TRANSFER BETWEEN VARIOUS TEAMS ACTIVE TOP LEVEL MANAGEMENT PARTICIPATION COLLABORATIVE DATA EXCHANGE BETWEEN INVOLVED STAKEHOLDERS	KNOWLEDGE MANAGEMENT, PROCESS & OPERATION 7B. WHAT COMPETENCES ARE NEEDED IN THE TEAM? R&D, ENGINEERS, DESIGNERS NAME OF THE FLOW TO BE IMPROVED: PRODUCT DATA FLOW BETWEEN INDEPENDEDNT SYSTEMS AND USERS FROM WHERE IS THE PHYSICAL OUTPUT SHIPPED? INDUSTRIAL AUTOMATION DIVISION, ABB. (GLOBAL LOCATIONS INCLUDED)	PLM FOUNDATION THAT CAN BE INTEGRATED INTO THE SYSTEM SEAMLESSLY IMPLEMENTATION ROADMAP RETURN ON INVESTMENT CHANGE MANAGEMENT STRATEGY	DATA GOVERNANCE (OWNERSHIP, TRACEABILITY, SECURITY, RELIABILITY, SCALABILITY) 4. WHAT ONE MEASURE(y) SHOULD BE UNDERSTOOD AND IMPROVED? HOW WILL YOU KNOW WHEN THE INTENDED IMPROVEMENTS IS ACCOMPLISHED? UNINTERRUPTED WORK FLOW , DATA FLOW FROM ABB PRODUCTS TO ERP's 5. WHAT IS THE BASELINE OF THE y AND CAN THAT PRECISELY BE MEASURED TODAY ORIGINATION OF DATA, DATA FLOW BETWEEN SYSTEMS, 6. WHAT OTHER Y CAN NOT BE LOST IN THE PROCESS (CONSTRAINTS)? DATA STANDARDS, ISO STANDARDS AND IS/IT GUIDELINES, LEGAL REQUIREMENTS	CAD USERS DATA MANAGERS DESIGN ENGINEERS ERP USERS

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