PROPOSED CONFIGURATION MANAGEMENT II BASED ENGINEERING CHANGE MANAGEMENT FRAMEWORK IN PRODUCT LIFECYCLE MANAGEMENT (PLM) SYSTEM

BAHADIR ÇİLOĞLU

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ABSTRACT

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ÇİLOĞLU, Bahadır
M.Sc., Department of Computer Engineering/ Information Technology Program
Supervisor: Asst. Prof. Dr.Sibel TARIYAN ÖZYER

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The global playground where companies are trying to succeed today has gradually become unforeseeable: The product lifecycle has shortened, becoming much shorter than in the past, and a good consumer differentiation is suffering from the worldwide market, due to an increasingly large product mix. Although previous studies have suggested models for Engineering Change Management (ECM), they were mostly focused on deficient criteria for ECM. ECM experiments have also provided useful findings from the viewpoint of the Product Lifecycle Management (PLM) architecture domain. Nevertheless, few of these studies indicated a structure under Configuration Management II (CMII).

This study presents a Change Management (CM) framework based on CM-II theory for PLM. In this context, related concepts are defined, then the engineering change framework is proposed by the author. Three of the studies were accompanied by definitions of common ECM fields of emphasis, identifications from a prior observational study, the vital success ECM considerations, and the creation of a suggested structure.

Firstly, the findings of this analysis expand the scope of the architecture domain of PLM alone to integrate the manufacturing domain of ERP for ECM research relative to previous ECM studies. Second, from the standpoint of framework assessment, only a desig wide perspective rather than design centric whom backbone of CM.
Keywords: Product Lifecycle Management (PLM), Engineering Change Management (ECM), Configuration Management (CM), Configuration Management-II (CM-II)

ÖZ

ÜRÜN YAŞAM DÖNGÜSÜ YÖNETİMİNDE KONFİGÜRASYON YÖNETİMİ II YAKLAŞIMI İLE MÜHENDİSLİK DEĞİŞİKLİK YÖNETİMİ ÖNERİLMESİ

ÇİLOĞLU, Bahadır
Yüksek Lisans, Bilgisayar Mühendisliği Anabilim Dalı/ BilgiTeknolojileri Programı
Tez Yöneticisi: Dr. Öğr. Üyesi Sibel TARIYAN ÖZYER

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Bugünlerde şirketlerin başarılı olmak istedikleri küresel piyasalar, baz yönlerinden dolayı öngörülmez hale gelmeye başlamıştır.Bu noktada ürün yaşam döngüsünün süresi eskisine göre azalmıştır ve tüketici ihtiyaçlarının farklılaşması sonucu piyasalarda ürünlerin çeşitliliği de artmıştır. Yapılan çalışmalarda Mühendislik Değişikliği Yönetimi (MDY) için modeller önerilmesine karşın, bunlar MDY için yeterli kriterlere odaklanmamıştır. Bu kriterleri karşılayan çalışmalarda da Konfigürasyon Yönetimi II (KY-II) teorisini kullanan ve Ürün Yaşam Döngüsü Yönetimi (ÜYDY) etki alanında MDY modellemesi yapan çalışma pek azdır. Bu çalışma ÜYDY için KY-II teorisini kullanan MDY çalışma çerçevesi sunmaktadır. Bu bağlamda ilgili kavramlar tanımlanmasından sonra MDY çalışma çerçevesi yazar tarafından önerilmiştir. Çalışmada ÜYDY ve Ürün Yaşam Döngüsü (ÜYD) boyunca değişikliğe sebep olabilecek etkiler, değişiklik yönetimi teorisi, MDY teorisi ve ÜYDY sistemi pratiği incelenmiştir.

Çalışmanın sonunda önerilen MDY nde yer alan yeni prosesler ve prosesler arasındaki bağlantılar ÜYDY sistemine yeni çalışma alanları yaratmaktadır ve ÜYD'nin Kurumsal Kaynak Planlamasında (KKP) çalışma alanını genişletmektedir. MDY, KY-II

teorisi yardımıyla tasarım bazlı olmaktan çıkıp üretim ve tedarik süreçlerininde katıldığı bir süreç halini almıştır.Sunulan gelişmiş MDY mimarisi, tasarım bazlı yönetim yaklaşımına sahip KY değil de, kurumsal bakış açısı olan KY-II prensiblerini kullanmıştır
Anahtar Kelimeler:Ürün Yaşam Döngüsü (ÜYD), Mühendislik Değişiklik Yönetimi (MDY), Konfigürasyon Yönetimi (KY), Konfigürasyon Yönetimi-II (KY-II)

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LIST OF ABBREVIATIONS

AMC : American Motors Company
ALM : Application Lifecycle Management
AI : Artificial Intelligence
AR : Augmented Reality
AP : Asia Pacific and Japan
BOM : Bill of Material
BPM : Business Process Management
BPMS : Business Process Management System
BPC : Business Process Change
CI : Configuration Item
CM : Configuration Management
CM-II : Configuration Management II
CAD : Computer-Aided Design
CAE : Computer-Aided Engineering
CAM : Computer-Aided Manufacturing
CSM : Component and Supplier Management
CAPE : Computer-Aided Production Engineering
CAPP : Computer-Aided Process Planning
CIM : Computer-Integrated Manufacturing
CPPS : Computer Physical Production Systems
CAGR : Compound Annual Growth Rate
DM : Digital Manufacturing
DECM : Digital Engineering Content Management
DMU : Digital Mock-Up
EDM : Engineering Data Management
EDI : Electronic Data Interchange

EDA : Electronic Design Automation

ECM : Enterprise Content Management

ECM : Engineering Change Management

EDM : Engineering Data Management

EMEA : Europe the Middle East and Africa

EC : Engineering Change

ECO : Engineering Change Order

ECR : Engineering Change Request

ERP : Enterprise Resource Planning

FEA : Finite Element Analysis

GTIN : Global Trade Item Number

IFPS : International Federation for Produce Standards

ISO : International Organization for Standardization

IM : Innovation Management

IoT : Internet of Things

ICT : Information Communication Technology

IS : Information System

IT : Information Technology

KBS : Knowledge Based Systems

LCA : Life Cycle Analysis

LEI : Lean Enterprise Institute

MRP2 : Resource for Manufacturing Planning

MRP : Manufacturing Resources Planning

MSS : Management System Standards

OHSAS : Occupational Health and Safety Assessment Series

OECD : Organization for Economic Co-operation and Development

PLM : Product Lifecycle Management

PDM : Product Data Management

PLU : Price Look-up Code

PIDEX : Petroleum Industry Data Exchange

PC : Personal Computer

ROI : Return of Investment

R&D : Research and Development

SA : Social Accountability

SCM : Software Configuration Management

SMS : Smart Manufacturing System

SaaS : Software as a Service

UPI : Unique Product Identifier

www : World Wide Web

WIP : Work In Progress

OCM : Organizational Change Management

ECM : Engineering Change Management

ÜYD : Ürün Yaşam Döngüsü

ÜYDY : Ürün Yaşam Döngüsü Yönetimi

KY : Konfigürasyon Yönetimi

KY-II : Konfigürasyon Yönetimi II

MD : Mühendislik Değişikliği

MDY : Mühendislik Değişiklik Yönetim

KKP : Kurumsal Kaynak Planlaması

IR : Incident Report

ECR : Engineering Change Request

ECN : Engineering Change Request

PR : Purchase Request

CHAPTER I
BROAD DEFINITION OF PLM

Product lifecycle and the management of the product life cycle is a widely studied topic in the business environment. The reason why it is popular is that it is a key point for the company's success. There are different theories of the product life cycle that circulate in academic circles. Though it shares the same title, the contemporary theory of Product Lifecycle Management (PLM) differs from that of the early 20th Century PLM theory [1]. PLM is an automated, data-driven management business model that accelerates creativity and successful product launch. It is based on common access to all product-related information, data, and processes to a single repository. It is the process of managing the whole journey of a product in the market, from its launch to its retirement. The life cycle includes the phases of introduction, growth, maturity, and decline [2].

PLM is an organizational approach for the development of a corporate management environment that focuses on Product Data Management (PDM). Owing to the need to handle complex product structures in the automotive and aerospace sectors, PLM first developed and consisted of Computer-Aided Design (CAD) and PDM systems. Since then, skills have been established that meet the demands of disciplines such as project management, process management, resource management and supply chain management, and have reached their present shape. PLM seeks to ensure cooperation and coordination through the entire life cycle of a product, from concept to post-sales operation, between all stakeholders of a company and its supplier [15]. As a technical solution, the organization uses a variety of tools and technology to provide a forum for data processing to develop communication between the benefits of hiring, to simplify knowledge flow at every point of the product life cycle. Due to PLM and its ability to build a viable market plan, it is distinct from other technological strategies.

A modern age for design project started with the invention of CAD systems in the early 1980s. The creation of hierarchical product structures by CAD systems was made possible. In subsequent years, the production of computer-aided engineering and manufacturing systems (CAE/CAM) has relied on computers like never before. In the near future, the need for a systematic method for monitoring the enormous amount of data generated in comparatively short periods culminated in the development of PDM. As a result, the infrastructure and existing product design process knowledge can be viewed conveniently, efficiently and accurately. Thanks to their capacity to act as central data warehouses, early PDM systems could provide their users with the necessary data. In addition, these programs involved the need to guarantee the accuracy of records, continuously synchronizing information and controlling how records were generated and updated [16].

In the history of PLM, the original product lifecycle concept, though it was mainly focused on marketing needs and conceptions, oftentimes drifted away into regions that didn't relate to marketing purview. So it is natural that the theory tends to be in relation to other related fields. The need to develop such a strategy originated from the necessity of a coherent framework that can explain the success or the failure of a specific product in the market [10]. The metaphor for having a life implies that the stages of the product's journey are fixed and non-negotiable [1]. American Motors Corporation (AMC) was one of the first major companies to apply the theory to practice. AMC focused on strengthening the product life cycle of its prime products to speed up the product development process to compete better with other companies that had a larger market value. The management of the product life cycle of AMC was so successful that the company was bought by Chrysler. The system was extended across the business, linking everybody involved in the design and production process [3].

Before examining how a well-managed product lifecycle has advantages for businesses, it is logical to summarize the phases of the product lifecycle. In introduction stage, in which the product is first introduced to the market. It is generally the most expensive phase of the journey of a product. The company usually leans heavily on marketing and promotion in order to establish reliability and popularity in the marketplace. The market size for the product is relatively small since there are fewer

competitors; naturally, sales are low. The growth stage is generally characterized by increasing sales and product popularity. The number of alternatives to the product rises. Other businesses become aware of the product and come up with their own; competition increases. As a result, the market expands. The prices may tend to drop because of high competition; however, sales continue to increase, and the product's popularity is still on the rise. The company may decide to push more on promotion and marketing because of the high competition. A product's maturity corresponds to the term in which the sales usually slow down or even stop. That means the market is saturated. The maturity stage is the stage in which the competition is highest. The company aims to maintain the market share they have built up in the previous stages. At the shake-out point, less successful competitors are pushed out of the market. Businesses may want to come up with different ways to attract consumers. Because the product reached its popularity, methods like versioning or making innovations may be effective in reaching different market segments. For successful products, the maturity stage is extended for a long period of time. Examples include Coca-Cola, Ford Focus, etc. A decline of a product is inevitable. Whether the product is successful or not, every product will be out of the market in the end. In the decline stage, the market has already narrowed down. There are different reasons for the shrinking of the market. Consumers may have lost interest and switched to a different type of product, or they may have already bought it. Either way, the product lost its popularity in the market. Although this process is inevitable, companies can still make a profit by switching to less-expensive production methods and cheaper markets [4].

Good management of the product life cycle is crucial for businesses, in that it supports the company's success in numerous ways. First and foremost, PLM is of utmost importance in terms of business strategy. Furthermore, it also enables companies to estimate the influence of the product on the market and analyze customer behavior. Let's analyze the benefits of PLM in detail. PLM supports centralized management. By allowing everybody to access the data information from a single hand, PLM reduces the risk of mistakes being made due to incorrect information. Planning, engineering, and production activities can be facilitated through the usage of a single source of information. Centralization of the management of the data product development process accelerates. Design and production teams work better and faster. Online workflows speed up the

production process and thereby make it easier to adapt to changes and make decisions faster. PLM also is effective in reducing costs. Because of the existence of a single source of authority, there is a decrease in prototyping and scrap costs. Re-use of the existing data lowers the cost of new prototypes . In the information age, enterprises need to control and utilize information now more than ever. The need for objective information for the accountability of a given organization has become more important. PLM systems guide business managers in their decision-making processes because these systems cover all business stakeholders. They are also resistant to manipulation of information and establish a structured information resource [5].

Another benefit that PLM offers is high productivity. By removing non-value-added tasks, streamlining, and automating workflows, and internal processes where possible, PLM enables businesses to improve operational efficiency. Because all the product, project, and manufacturing data are stored in one central location, teams can search, navigate, and reuse the information faster than ever. A well-managed product lifecycle supports the company's relationship with the customer. In a PLM applied business, the customer service team can provide feedback directly into the PLM platform. This way, the feedback can be reviewed by engineering, operation, and production teams and ensure that customer satisfaction is increased [2]. Renewal, production of the goods and equipment for them in a globalizing environment with strong competition. The success of businesses has acquired creative characteristics more significance than ever. On the one side, businesses aim to adapt their plans to the circumstances of competition. On the other side, they attempt to create lean value structures focused on waste management and to reduce their costs. This concept is articulated as a lean value philosophy from the corporate plan to the organization as a whole [17]. Enterprises are obligated, to build a lean value framework, to incorporate their governance frameworks into this framework. This integration requires quick, available, and accurate knowledge to be used in decision mechanisms. The use of knowledge in decision mechanisms must also be democratized in order to create a lean management framework. Decisions made based on departmental managers' reports could lead to questionable outcomes. Liberalized information can be characterized as information gathered and structured without being processed through arbitrary filters of entities. It refers to data which come from the

corporate memory, are reviewed, and organized using control parameters. Such a source of information provides access to an interest-free decision process [18].

PLM enables businesses to manage the lifecycle of the product in the market and the information flow. A well-managed PLM system allows businesses to keep up with other competitors in international and global markets. It is considered that PDM is a subset of PLM. Engineering Data Management (EDM) and PDM emerged in the late 1980s since a need to keep track of design files was felt by engineers. PDM enabled engineers to have overall detailed management of production data. This way, the process of information management was accelerated, and the risk of incorrect information was reduced. Through making changes in policies, practices, and methods and controlling the product life cycle, PLM benefits companies in different fields. Furthermore, by stimulating innovative changes in products and allowing them to make informed changes in the lifecycle of products, PLM helps businesses in a broader sense. Apart from including items, Bill of Material (BOM)'s and documents, PLM also incorporates information regarding analysis results, quality standards, manufacturing procedures, product performance information, etc. Modern PLM supports collaborative workflow. Online systems enable workers from all around the world to work together, and with outside organizations. Through advanced information retrieval, electronic information sharing, data reuse, and numerous automated capabilities, with greater information traceability and data security, working teams work efficiently. Moreover, PLM accelerates the processing of engineering change orders (ECO) and responding to product support calls. Handling of bids and quotes, exchanging product information, and access to the required engineering data by service technicians and spare part sales reps are smoother and more efficient with PLM. Many companies report pay-off periods one to two years or less based solely on reduced development costs. By giving opportunities to control product margins more carefully and to remove poorly performing products from the markets and enabling companies to boost revenue streams through hastening the innovation process. PLM is essential for competitive markets since it makes Return of Investment (ROI) incredibly challenging. PLM enables companies to control the product life cycle and general management of the information flow. Generally, the PDM and PLM abbreviations refer to the ISs developed to manage the product life cycle [6].

Creation, preservation, and storage of product information is essential for PLM to ensure the accessibility and reutilization of the data. The existing work should remain exploitable and the data should be converted to capital easily. While the product life cycles are shortening, conventional manufacturers are looking for ways to provide services covering the whole lifecycle. Management of the whole lifecycle gains importance in certain industries. Apart from PLM and lifetime service, the term extended product gained a new meaning in this atmosphere. Service functions are crucial for the extended product for the whole lifecycle. Because of the high competition in the global market, customer satisfaction is of the utmost importance for companies. Adapting to the changes and making alterations in products can make a difference in the market. Collaborative production between companies is essential for the modern business world. The principal should be able to manage the different chains of production. Irregular order of networks may be problematic. Data management is crucial for companies selling products in a wide range. Electronic storage of the vast amount of data eases the data management process. Making changes to a product can be challenging for large businesses. All contributing parties must have access to the latest product data. Furthermore, as the improvements are designed, it should be possible to see the impact of changes to product components. There are various IS in the modern industry and yet different parties may be using different systems. Providing unity among these IS may be challenging but it's possible. PLM integration process involves various detailed information about the products of the company[6]. Products and details obtained from product specifications can be linked to business operation. If customer demands support these conditions, the value chain is preserved, and some of the most comprehensive steps in the process. In the same way, the engineering of market incorporation functions to guarantee the integrity of the chain. Continuous development techniques emphasize lean quality structures on process waste reduction. For years, PLM programs have performed their original responsibility of controlling product production activities and maintaining fast market penetration. In addition to the process change needed for lean value processes and the need to document these changes in the organization's mind, PLM is a category of processes that give companies interconnected enterprise organizations that are needed for business architecture engineering. In addition, it helps organizations to develop decisions based on

relevant facts which encourages constructive steps to be taken. At the level of digital transformation, an important tipping point awaits the sector, the importance of a quality management approach will increase. The backbones of information on inventory management of PLM applications are among the applications used commonly by organizations undergoing transition Industry 4.0 [19]. Under certain terms, the frequent practice of businesses in favor of PLM procedures is projected to become reality over the next decade.

1.1 PRODUCT LIFECYCLE PHASES

Product lifecycle generally refers to the process that a certain product undergoes from when it is first introduced to the market until it's removed from the market due to different reasons. While some products may stay much longer compared to others, these products will inevitably disappear from the market in the end. The product life cycle theory was first put forward by an economist named Raymond Vernon in 1966, as a response to the failure of the Heckscher-Ohlin model, which is a general equilibrium mathematical model of international trade, in explaining the pattern of international trade [7]. According to Vernon's theory, every product that we encounter in our life has a limited amount of existence on the shelves. Throughout this existence, products go through four different phases: Production, growth, maturity, and decline. The theory of the product life cycle originates from the theory of diffusion and adoption of innovations [8]. That is, sales are low in the introduction phase since few customers are aware that the product is in the market. During the growth period, sales start to climb up and the products become accepted and recognized by customers. However, the sales rate will start to dwindle as new competitors start to enter the market and the market narrows down. Finally, the sales reach a plateau. This corresponds to the maturity phase. Now that the product has been sold to most of the mass market, sales will decrease rapidly, and eventually, the product will be removed from the market. There are 4 phases which are introduction, growth, maturity and decline of product life cycle. The introduction phase is the first phase of the existence of a product in the market. And it is usually at this period the company that sells the product makes the most expense. The company spends money to put the product forward in the market. Lots of marketing and promotion activities take

place during the introduction stage. Famous launch presentations of Apple, where their new products are showcased to the whole world, can be given as an example of these marketing and promotion activities [8]. During this stage, the company can estimate how the product is perceived by the mass market and whether the product will be a success or not. However, there is no guarantee that the product will meet the deficit through sales. The growth phase refers to a stage where the product takes off and becomes recognized by the marketplace. The product is popular, and sales are high [8].

Since a new growing market attracts attention from the competitors, this is the ideal time to increase market share. Because there are new competitors in the market, the company should differentiate their product and modification of the process of production will be effective to discourage other competitors from entering the market. Marketing and promotion are lower compared to the previous stage but if the competition for the product is especially high, the company may still invest in marketing. But still, because the sales rates are high, marketing at this point is usually aimed at increasing the product's market share. During the maturity phase, product sales tend to slow down and even fall. It is a period which indicates a saturated market. There are alternative products with variations signaling other competitors in the market. At this point, a company that reached its market share goal will benefit most. The shake-out point will eliminate the less successful competitors from the market. Competition factors like distribution, pricing, and discount policies will be constantly changed according to the situation that the market is in. The maturity period may last for a long time span, which is a good sign for a product since it marks the permanence and success of the product in the market. Until the decline phase, the product has already made its name in the market and is familiar to the customers. During this stage, sales rates decrease significantly and customer behavior changes. The company loses its market share and competition damages the sales even more. No matter how long the maturity stage is, the decline and the removal of the product is inevitable [9].

1.2 OPPORTUNITIES OF GLOBALIZATION IN PLM

There is no definitive definition of globalization that applies to every context. But generally, globalization refers to the process by which the world economy becomes more

interconnected, leading to a global market and a global culture. With a dramatic development in the channels of communication, as in every aspect of production and marketing, lots of different industries emerged all around the world. Verter [10] argues that: “The significant element of economic globalization is the integration and expansion of world trade and financial flows through the abolition or reduction of trade barriers such as import tariffs, quotas, and liberalized foreign investment rules. According to the Organization for Economic Co-operation and Development (OECD) (2008), Multinational Corporations (MNCs) have been providing capital flows, the so-called Foreign Direct Investment FDI, which serves as a major vehicle for local enterprise development. It also helps improve the competitive position of both the receiving (“host”) and the investing (“home”) economy.

Because the world has moved to a different direction and cultures and markets got more and more closer, the need for a change emerged in every aspect of the product chain. Advancing technology and changing consumer behavior pushed companies to look for alternative waves of management. The companies and staff need to adapt to changes fast, now more than ever. The competition and the race for global reach can be very frustrating for companies that don’t know how to adapt their PLM into a new age of marketing and production. Managing the product life cycle at this point is very crucial for company success.

PLM is of utmost importance for effective teamwork and collaboration activities. Without effective management of the life cycle of a product, it is impossible to maintain a stabilized and efficient flow of trade. If there is no standard product definition supported by PLM, management and synchronization of design efforts and spread across multiple sites worldwide in different time zones can be very hard, almost impossible. Considering the language barrier, the production of a good in different parts of the world can be very frustrating in terms of communication with other parts of the production chain. This is why the management of the product lifecycle should not be overlooked. A solid foundation of the PLM will make it possible for developers to make it seem as if they work in a building, even though they may be scattered all around the world. To explicitly cover traditional functional decompositions and physical 3D visual representations, the framework must have real-time coordination going beyond geometry [7].

PLM enables the conduction of the process from a single central office. General Motor GM synchronizes on the order of 30,000 CAD files or 70 Gigabytes every day. PLM must scale to a huge number of users while simultaneously covering an unusually broad scope of data. A standard functional and physical product structure can be defined and shared across sites and platforms. Everyone talks the same language in terms of the definition of the product. PLM can help to promote a common language worldwide [11].

PLM technologies are being utilized in many different fields. Manufacturers look for alternative ways to cut operating costs. PLM has evolved from an engineering-centric concept to a strategic enterprise type of initiative. It makes it possible to read the global market and act accordingly to the changes. It will be easier to spot the mistakes at that very moment and change perspective. An analyst at Gartner Inc., Marc Halpern, argues that: "PLM has evolve from an Engineering-centric idea to a Strategic Enterprise type-of-initiative" Plane, a Piscataway, N.J.-based unit of American Standard Cos. that makes air conditioning systems, is currently implementing PLM technology as part of a broader effort to improve its materials reuse and configuration management (CM) processes [12]. As we can see, a well thought out system of PLM can easily make things easier for a global company or a company that wants to take a similar route and work collaboratively around the world. However, this system of management should be implemented in the most diligent way possible and leave no space for doubt. There will eventually be problems that come with globalization, like the problems that may occur because of miscommunication between regions, business risks that may emerge because of a lack of information about the market, etc. In the end, however, a solid base for a PLM system will dramatically increase efficiency.

1.3 IMPORTANCE OF PLM

Expired products must be swapped with fresh ones to maintain profit, product life cycle model suggests. Predictions and estimations can be made thanks to the model of product life cycles. It can raise awareness about the capacity and decline of the product, and the problems arise from these stages. Combined marketing strategies can be applied about product price, promotion, and distribution thanks to product lifecycle. The model can also be beneficial for understanding the development of certain marketing strategies

along the stages of product life cycle. The advantages of forecasting the lifecycle of a product are as follows. The models can be used to make healthy marketing decisions at diverse stages. Any precautions should be taken where the product life cycle is predictable before the decreasing period of the product. It can be achieved through model adjustment, pricing practices, style separation, changing in standard, etc. Knowing an inventory's product life cycle helps the business to pursue an appropriate plan for development. Management can motivate new modes of product use, especially during the stages of development and maturity. Product design and efficiency can be improved by implementing the latest technical modifications. The administration will relinquish the item which the customers do not order [13].

A product's life cycle has a significant impact on decisions related to the use of media. In every phase of the product life, a conscious job holder can make proper decisions to create and sustain the awareness about products. The product life cycle is shaped by their hearings from other people and mass media. It is important to protect the gained attention but also ensures that there is always an opportunity to attract the new possible clients. At some point, the product or service faces a decreasing conversion rate. In case that happens, usage of media should be diminished until an entirely new product has been introduced. If the new product is released; the Product life cycle starts over, and the marketer starts to pay attention to creating attention, demand, preference and eventually a purchase decision [14].

1.4 APPLICATION OF PLM

BOM applications define product attributes. Regulation of Materials Bills is executed by BOM applications. Definition (Bill) of the "things" (materials) that make up a product or assembly. The things may be the ingredients of the food product, or the intermediate sub-assemblies that make up a mechanical product assembly, depending on the stage and the product. In the product life cycle, there can be many BOM structures. Users tend to work in the process that better fits the work they have to perform at all points in the product life cycle. Popular structures are the Engineering BOM (eBOM) which from the point of view of a design engineer, defines the items in a product. Manufacturing BOM (mBOM) that describes from a manufacturing point of view the products in the product,

and Service BOM (sBOMs) that describe them from a service engineer's point of view. Managing multiple systems for many items, while also managing them, it's almost impossible manually. BOM apps is one of the first computer programs in the manufacturing industry. BOM program facilitates the development and modification of BOMs, preserves consistency between the various systems and different opinions on the product, based on the place in the lifecycle of the product [20].

Augmented Reality (AR) is a modern human-machine interface that overlays the real-world environment with simulated computer-generated data. In many areas, such as military preparation, surgery, entertainment, repair, assembly, product design and other manufacturing activities, strong potential applications have been found in the last ten years [21]. AR equipment to replicate, assist and optimize these phases of development before they are carried out. This will ensure that tasks such as modeling, preparation, machining, etc., without the need for subsequent rework and adjustments, are executed properly for the first time. The view of data and the overlay of images are context-sensitive, which means they depend on the objects observed [22].

A Digital Twin is a digital copy of a human being that is alive or non-living. Digital twin refers to a digital copy, which may be used for multiple uses, of future and existing physical valuable things, processes, people, locations, systems and computers. A wide variety of developments are facing the worldwide production sector. Examples include engaging with multiple types of consumer demands, growing labour costs and costs of energy supply, linked to environmental conditions or the health of Earth's emissions, and concerns about progress. Smart manufacturing systems (SMS) have the power to handle them, based on the experience of industrialized countries and multinational manufacturers. Using the expertise of manufacturing, the Internet of Things (IoT), SMS will connect raw materials, production processes, logistics firms and maintenance schedules. These links establish computer-physical production systems (CPPS) and relation functions across the lifecycle of the entire thing. These ties are feasible today because of the developments in digital manufacturing (DM) technology that can assist in CPPS factory design, overhaul, and review and help to improve factory output constantly and in a way that outputs a loT with very little waste management.[23].

Other Application:

Additive Manufacturing

Application Lifecycle Management (ALM)

Artificial Intelligence (AI)

Augmented Reality (AR)

Compliance Management

Component and Supplier Management (CSM)

Computer-Aided Design (CAD)

Computer-Aided Industrial Design (CAID)

Computer-Aided Manufacturing (CAM)

Computer-Aided Production Engineering (CAPE)

Computer-Aided Process Planning (CAPP)

Computer-Integrated Manufacturing (CIM)

Data Exchange

Digital Engineering Content Management (DECM)

Digital Manufacturing (DM)

Digital Twin (DT)

A Digital Mock-Up (DMU)

Electronic Data Interchange (EDI)

Electronic Design Automation (EDA)

Enterprise Content Management (ECM)

Engineering Data Management (EDM)

Factory Automation

Finite Element Analysis (FEA)

Geometric Modelling

Haptic Applications

Innovation Management (IM)

IoT Platforms

Knowledge Based Systems (KBS)

Life Cycle Analysis (LCA)

Machine Learning

Manufacturing Automation

Manufacturing Resource Planning

Numerical Control

Parts Catalogue

Parts Libraries

Phase-Gate

Portfolio Management

Product Data Management (PDM)

Project Management

Rapid Prototyping

Requirements Management

Reliability Management

Simulation

Software Configuration Management (SCM)

Service Management applications

Technical Document Management

Technical Publication

Translation Management

Virtual Reality

Virtual Engineering

Virtual Prototyping

Visualization and Viewing.

3D Printing

3D Scanners

Data Management/Document Management

Part Management/Product Management/CM

Process Management/Workflow Management

Program Management/Project Management

Collaboration Management

Visualization

Integration

Infrastructure Management

Idea Management

Product Feedback Management

CHAPTER II
PRODUCT

In marketing, the product generally refers to the goods or services that a business offers to the market that aims to satisfy a need or want, as a result of various processes. Types of products are not limited to tangible items; the definition also involves intangible products. These may be events, places, persons, organizations, and ideas [24]. A product is the key element for an enterprise, it is the focus of all the business-related activities. Without the product, the company would not have anything to win on the market. The business reliability is directly linked to the product quality. In the globalized market, there are various types of products. The market gives consumers alternative ways of satisfying their needs, whether it is buying the item or buying the service. These products are generally classified into different classes to simplify the identification and description. Conventionally, it is considered that there are 3 main types of products:

Consumer products, which include convenience products, shopping products, specialty products, unsought products, industrial products, and services. Consumer products are the end products that the customer sees on shelves, websites, or any other alternative shopping platform. They generally appeal to personal desire. There are consumable products, which don't last long, like a bottle of water, and there are durable products, like an automobile, which the consumer uses for a longer period. Industrial Products are those products that are bought in a manufacturing or business phase for further processing. The key distinction between consumer goods and industrial products lie in the use for which they are purchased. Services are intangible products. They may be events, organizations, or actions. It cannot be stored or owned. Examples include banking services, postal services, etc. [25].

A company's integrity is all about the product. Product classification, variation, and innovation are different factors that influence a business's success. In terms of PLM,

management of product data and product traceability is of utmost importance since they have an enormous influence on how the company is perceived by the mass market.

2.1 PRODUCT STRUCTURING & BOMs

Any good service or system offered in the market for consumer use is generally referred to as a product. Products are taken as raw material and undergo phases like design, engineering, etc. After this process, the end product is sold as finished goods. Product structure management can become unmanageable as a company becomes more receptive to particular customer tastes and derivative goods evolve to suit the particular configurations [26]. Having a detailed knowledge of the product and its journey is of prime importance for a business. Knowing what kind of operations that a product undergoes, for instance, or understanding its lifecycle in the market, being able to classify and categorize a product, having the information of its parts, content, and components are essential for a company because it has the potential to shape the company's business model. This information can influence engineering and design activities and also provide insight into marketing and promotion. PLM is a great example of how being able to control the processes product lifecycle and being aware of the possibilities that come with it can make significant changes in the company strategies. Product structuring, or BOMs, is another layer in the whole process of manufacturing that supports the company's understanding of the product's entirety.

The product structure gives a hierarchical classification of the items which form a product. With the product structure, the understanding of the components which compose a product as well as their attributes can be described. The product structure shows the raw materials, parts, and sub-assemblies in a hierarchical order that illustrates the grouping of items on an assembly drawing or the grouping of items that meet at a point in the development process [28]. The product structure, which is generally shaped like a tree, may vary depending on its purpose. From an engineering perspective, a breakdown regarding the functional systems and subsystems is more preferable. On the other hand, a breakdown following the assembly of the product may be preferred from a manufacturing perspective. The most popular type of product structuring for manufacturing purposes is the BOM [29]. BOMs, the product structure for manufacturing-related activities, generally

refers to the structured relationship among product items and connects all the information that is related to the product and its features [27]. It roughly means the list of components, parts, raw materials and instructions, and quantities required to manufacture, construct or repair an end product. It also includes all the parts of the object with the name, reference number, quantity, and unit of measure of each component [28]. A BOMs is generally used to understand the product's essence. Managing the structure of a product helps to facilitate the production and management of configurations of goods, to keep up with new versions and design variations, connect product definition to the structure, enable various discipline-specific views of product data and structure, etc [29]. There are various forms of BOMs for different purposes. The most popular of these fields are engineering and manufacturing. Two different structuring methods will be analyzed before advancing on explaining the importance of BOM. The engineering BOMs define the design of the finished product. It usually lists products as they are shown on assembly drawings according to their relationships with the parent product. BOMs for engineering projects will include the product code, part name, part number, part revision, description, quantity, unit of measure, size, length, weight, and specifications or features of the product. However, this data may not be sufficient to demonstrate the grouping of components at each point of the manufacturing process, nor to include all the data necessary to support development or procurement. That is why the structure of the product may be rearranged accordingly in order to provide assurance for manufacturing [28]. A manufacturing BOMs, unlike the eBOM which includes data regarding the design of the product, includes all the information as to the assemblies, product parts, and components that are needed to prepare the finished item to be shipped. Furthermore, mBOM also incorporates the packaging materials required to send the product to the customer [30].

2.2 COMPONENTS OF THE BOMs

Since the main purpose of the BOMs is to make sure that the product is built in the right way, there are some specific pieces of product information that a BOM should include.

BOM level assigns each part or assembly a number that indicates where it fits in the hierarchy of BOM, which helps the BOM to be deciphered easily [29]. Part assembly code is a unique identifier that is assigned to a finished product ready for sale. It

distinguishes the product from other products in the market so that the traceability of the product is easier. Part assembly number, to reference and easily recognize product parts, a part number to each part or assembly is assigned. Either an intelligent or non-intelligent assembly numbering scheme is popular for manufacturers to choose from. It is important to separate the products, so avoiding confusion is essential. Part assembly name, unique name for each assembly makes it easier to distinguish product parts. Part assembly description provides a detailed description of the assembly which helps to distinguish the specific products among others and identify it. Quantity is the recording of the number of product parts that are to be used in each assembly or subassembly to make a guideline for purchasing and manufacturing decisions and activities. The unit of measure classifies the measurements in which a part will be used or purchased. Standard measures like inches, feet, ounces, and drops are favorable for classification. It is crucial to be consistent across all part types because the slightest mistake in the information chain can stir up trouble. The ensurement of the information that is delivered to the production line will reduce the risk of mistakes being made. Procurement type is documentation of how each part is bought or manufactured (i.e. off-the-shelf or made-to-specification) to achieve efficiencies in the activities of production, planning, and procurement. Revision level, identification of the material and document changes that are made in accordance with a change number by the use of revision level [31].

In contemporary markets, especially the global markets, the processes, and transactions are faster than ever. Companies adapt to the changes in customer behavior and work much more to attract new customers and come up with new ideas and new products. Increased diversity of products, greater technology complexity and shorter periods of innovation are some of the most critical developments affecting manufacturing enterprises at the moment. New markets emerge every day, and together with new markets, new competitors offer new alternatives for the usual consumers. Naturally, there happens a surplus of product-related information in the global market. Managing the product information flow is significant for any enterprise that wants to be successful in the market. PLM systems are of utmost importance for information management. PLM enables businesses to manage production data efficiently, guarantee the accountability of

the process over the extended supply chain, and support a paradigm shift from functional emphasis to the management of complete product life cycles [27].

Product structuring plays a huge role in the effective implementation of the PLM systems. Activities of product classification, versioning, or product structuring are core elements that can establish company integrity. The BOMs, especially, are vital because it guarantees that, when required, parts are available and ensures that the assembly process is as effective as possible. All product-related items and their structural relations are then handled by the product structure within the PLM. If the BOM is not accurate, it can slow down the production process, or it can even halt it, which will increase operating costs [28]. The BOM is significant for the flow of the product in the supply chain. As it is mentioned, inaccuracies in BOM will cause various damages to the production process and increase production costs. Good management of product structuring will support the product lifecycle and help the business to enhance customer satisfaction.

2.3 PRODUCT IDENTIFICATION

Customer satisfaction is one of the key points that a company should be able to maintain. The products that the company is made it's name should be efficiently flowing through the supply chain. The right product should be in the right place at the right time. There should be no space left for wrong labeling or distribution that may harm the reliability of the company in customers' eyes. In order to perfectly ensure the flow of the product accurately in the supply chain, the company should use some techniques to identify their product. These techniques include broad categories of labeling, brand protection, and various information labels to trace the product along the supply chain. Product traceability facilitates the process of tracking the product from start to finish. The ideal system would give the customer the opportunity to trace the process backward through delivery, shipment, manufacturing, and raw material acquiring phase so that the buyer can identify the supplies of the original raw material. Being able to trace the product as it moves along the supply chain has many benefits that increase the productivity and workflow in general. Tracing the product will enable the staff to interfere in a situation of an unforeseen recall, it enables the source of the problem to be swiftly identified and

rectified. Furthermore, it also makes it possible for the company to distance itself from the problem and highlight that their products were not affected [30].

So many of the different companies that are globally successful are now aware of the importance of being able to identify their product on the spot. You can now find numbers or unique identifiers, like codes, that are given to make it possible to trace the product anywhere in the world. Confidence in your products is vital for the skeptical world we live in these days, especially as brand loyalty is becoming increasingly fragile. As it is highlighted in, though smaller enterprises become aware of the importance of product traceability in an age of international trade, it is even more important for larger companies like Tesco, Mars and Coca Cola. "A solid framework in place makes it easier for businesses such as Tesco and Mars to easily spot when and where an obstacle shows up in the process and rapidly eliminate the possible risks from shelves." As it is mentioned before, by tracing the product effectively and solving the problems on the spot, the company preserves its integrity and enhances the relationship that is already established with its customer. Furthermore, as the world interrelates more and as the means of communication develop and become more accessible, customer behavior also evolves. The customer wants to know more about the quality of the product that they are buying. They want to learn more about the conditions that it is made of, where it comes from, how it has arrived on the self, and so on. Now that they are able to ask these questions easily, being able to trace the product is important now more than ever since it will provide the means to answer such questions. Considering the world that we are living in today, a company's reliability and integrity are of utmost importance. Customer service and the personal relationship that the customer builds with the company can be even more important in some cases. A solid understanding and workflow of product traceability will enhance the name of the company in the global market. First and foremost, the company should be able to track and follow the route where ingredients, parts, and materials come from, the process they undergo, and how they are distributed as end products. Identifying the specific parts, product quality, materials, safety, and labeling. There are some standard methods being widely put into practice in order to trace a product along the supply chain. The supply chain is visually activated by distinguishing the item uniquely. Depending on the product, package, and business needs, there are different ways of identifying fresh

produce. To help trading partners conduct business in a shared language, data standards are used to standardize processes and improve business efficiencies. Barcodes and identification numbers or Global Trade Item Number (GTINs) are used throughout the entire supply chain. As the product flows from the manufacturer to the shelves, data is collected at different points. Let's take a look at these different means of identification [33].

2.2.1 Popular Methods of Product Identification

There are several methods of identification. Some of them are much more precise and are able to identify the product on the spot-on short notice. These are generally referred to as "Unique Product Identifiers" (UPIs). Others, on the other hand, may not be as precise as UPIs but will help along the way to trace the product and build a company name in the market. These methods include branding, labeling, grading, packaging, etc.

Branding, a brand name, symbol, design, or a combination of them will enable customers to differentiate the product from other competitors' products. The decisions that the management makes regarding the brand image reflect the product's place in the market. Branding is a means of identification and differentiation. Together with branding comes the promotion and advertisement that helps the product to be popular among its rivals. Grading means qualifying the product with a distinctive rank, class, or value among other products. It is essential and practical to make the product popular and competitive in the market. Packaging, a good package will attract customers and strengthen the company's reliability and integrity. Furthermore, good packaging will protect the product along its journey in the supply chain. Labeling not only helps to identify the product among others, but it also helps promote the company's name. It may be a sticker, a tag, or any other creative output. It communicates directly to the customer and attracts them [34].

Although these are some of the popular methods that are widely used in 21st Century marketing, they are not as effective as UPIs. Though they help differentiate the product and promote it, the most important techniques of product identification are UPIs. The product that is sold on the global marketplace is identified by UPIs. They distinguish the specific product and help match the deals with search queries. The manufacturer assigns UPIs to each product, so if you sell the same product as another retailer, the UPIs

will be identical [35]. If the company wants to put its products on sites like Amazon, eBay, Walmart, or other online marketplaces, product identifiers are a must. Without product identifiers, the possibility of the online marketing industry working well is little. Here are some of the most popular UPIs:

Price Look-Up Code, the Price Look-up Code, or PLU, is a 4- or 5-digit number used mainly on fresh products and generally appears on a small sticker that is applied to a single piece of fresh produce. The PLU code identifies products depending on the group of commodities, variety, and size. Supermarkets use them to make check-out and inventory management faster, quicker, and more precise. The International Federation for Produce Standards (IFPS) assigns these numbers. IFPS's aim is to facilitate the fresh produce industry's supply chain efficiency by developing, enforcing, and managing harmonized international standards [36].

Databar or Barcode, can store varying amounts of data. These include the product's batch number, expiry date, item weight, etc. There are 7 symbols on a databar, four of them are used at the point of a sale.

GTINs are used to identify the company and the product to enhance and ease the workflow, especially the efficiency of the supply chain. They are used to identify an item or a package or case for fresh produce. The numbers are encoded in a barcode. "In the fresh produce sector, there are 3 different global trade item numbers (GTINs) used. They are 12, 13, or 14-digit numbers, respectively, numbered GTIN-12, GTIN-13 and GTIN-14. The product identification numbers used to identify products going through point-of-sale are GTIN-12s and GTIN-13s. The non-retail product identification numbers used mainly to classify groupings (such as cases) of identical retail products are GTIN-14s.The GTIN is the most commonly used standard in the world, being used in over 100 countries by more than a million businesses [37]

Manufacturer Part Number (MPN), an alternative identifier to GTIN. MPNs are product numbers used, similar to GTINs, to help identify special products in the database. However, unlike GTINs, MPNs are assigned by manufacturers [38].

Universal Product Code, a distinctive 12 numerical digits are mostly used for commercial products, typically associated with a barcode printed on retail products for consumer items. Used primarily in North America.

European Article Number, a distinctive 13 numerical digits are mostly used for commercial products. Like the Universal Product Code, it is also typically associated with a barcode printed on retail products for consumer items. However, it is mostly used outside of North America.

Japanese Article Number, 8 or 13 numerical digits used only in Japan.

International Standard Book Number (ISBN), composed of 10 numeric digits, is used globally.

MPN, alphanumeric digits are used globally. It is a number that specifies the product to its manufacturer.

2.2.2 Novel Methods of UPI

Together with the opportunities that technology brings to the industries, new methods of UPI have been developed. Here are some of the ways of UPI that are widely being put into practice day by day.

QR Codes, before barcodes, cashiers needed to enter the prices of products manually. Because of the inefficiency of this method, barcodes made the process much easier. Furthermore, the older way was much more prone to error. Barcodes also helped to decrease the number of simple errors in the workplace. However, throughout the years, the boundaries of the barcodes have been understood. Barcodes could only hold a limited amount of data, around 20 alphanumeric characters, to be precise. Naturally, a need for a more efficient system of data preservation emerged. The QR code, developed by a Japanese company in 1994, was different from a barcode in that it was 2D. It could hold the information in 2 directions. Both horizontally and vertically. The new code was a revolutionary change in data preservation. The QR code could code 000 characters and “could also be read more than ten times faster than other codes.”, according to the QR website. QR code stands for ‘quick responsive code’. However, in 2020, even QR codes can’t match the pace of our world. So, a need for a new way of data preservation emerged [39].

Invisible Watermark Codes, an invisible watermark code is a new generation of Universal Product Code that can be inserted into a product for maximum coverage and quick scanning. Unlike the QR code, which is only placed on a small space on the product,

the invisible watermark code is embedded all across the product's surface. The watermark code is undetectable and can easily be scanned through a smartphone, enabling consumers' connection with the company's mobile content. The codes can't be traced with a human eye, thereby it ensures the safety of the product's traceability. Being able to ensure the safety of its products is an essential capability for a company. As it is mentioned in this text, the ability to interfere in situations on the spot and solving the problems is of utmost importance for customer satisfaction. Customer behavior changes day by day. Competition in the global market is fierce and giving up on a product and preferring an alternative product is a matter of seconds. Customers want to know their product's history and want to do their operations rapidly. A company should be aware of the changes in the market and adapt to these changes. This is why product identification and traceability are significant for many businesses.

2.4 PRODUCT CLASSIFICATION (VERSION, VARIANT, OPTION, PRODUCT OWNERSHIP)

Product Classification is crucial for a business that wants to understand and adapt to the changes that are happening in the global market. It involves the ordering of products or services into groups classes based on their similarity or features. Though it sounds relatively simple to the ear. Product Classification is significant for a company to increase efficiency and act according to customer behavior. Product Classification is also important to be able to follow the global marketplace and to develop production and promotion strategies. As it is mentioned before, product classification will make it easier for the company to change and adapt to evolving customer behavior. Through the classification of products into relevant categories, the marketer will have the chance to decide which strategies and methods will help promote a company's product or service. It is not reasonable to adopt a similar method of promotion and marketing method for a wide range of products. Different services and goods will require different, and most probably creative, methods of marketing. The company will gain an advantage from product classification because it will help to decide on such confusing topics and support on developing business strategies. A well-categorized layout of products will also support the consumer experience. The customer wants the best price and a simple process of research.

The accessibility of products is essential for a smooth shopping experience. A well-built product taxonomy enables consumers to quickly and easily locate what they are searching for [39]. Usually, manufacturers categorize consumer goods based on the form of the purchase decision process. To sell products and services belonging to different groups of goods, various marketing techniques and instruments are used to promote products and services belonging to different classes of goods[40]. In the category of consumer goods, there are four main classifications: Convenience goods, shopping goods, specialty goods, and unsought goods. We will now take a look at these classifications and give specific examples for each. Convenience products refer to the most-accessible products on the market. They are the products that consumers buy frequently and without in-depth research or planning regarding the product.

Customers, for most of the time, make a decision only once for such products and repeat the decision over many purchases. Examples include soap, toothbrushes, candy bars, so on and so forth. Convenience products are low on cost and they are readily accessible for the mass market. Accessibility of these products in situations of emergency or impulse is usually effective [40]. Shopping goods are less regularly purchased consumer products and services that the consumer typically compares carefully based on suitability, quality, price, and style in the process of selection and purchase. Because shopping goods are priced relatively higher compared to convenience goods, the customer tends to look for alternatives and search more. Multiple retail stores are customarily visited. Usually, marketers sell their goods across fewer channels but offer deeper sales support to help clients compare their efforts. Examples include extremely large purchases like houses and cars, or relatively lower purchases like furniture, medical or dental care, etc. Promotion and marketing strategies matter much more for a company that sells shopping goods, compared to a company that sells convenience goods. Since the customers tend to look for better options, the company should adopt different ways to attract their customers, like lowering the prices, producing better products, or giving better customer service. Promotion is also important for shopping goods because it is significant for the company to differentiate its products from its alternatives to stand out in the market [41,42]. Specialty products are so infrequently bought items in that they are risky and expensive. They have specific qualities or other characteristics that make the product

especially valuable for the consumer and require a detailed decision-making process of problem-solving. Goods in the specialty product classification have a tendency to promote very impactful brand identities, leading to strong brand loyalty among consumers. Brand lovers positively influence brand loyalty and influence customer behavior [43]. Examples include Ferrari's, computers, iPhones, paintings by well-known artists, designer clothes. Customers of specialty products tend to have low price sensitivity, willing to pay whatever the price is. The company promotes the innovations and developments of the specific product rather than aiming at lowering the prices or other simpler marketing techniques. The goods in this group require very advanced retailing that can provide both before and after sales with a high degree of augmented product services [41,42]. The last category of products is "Unsought Goods". These are the products that buyers don't put much thought into buying, and don't have a compelling impulse to purchase it. They are often items that people purchase, such as life insurance or fire extinguishers, out of a sense of fear or danger [41].

Product versioning simply refers to the offering of a product in different forms for different market segments. It is a market strategy that allows the company to offer more choices to its customers without having to come up with new products or adding significant production costs. A good strategy of versioning will benefit the company's income in different ways. It will attract customers and thereby help to make more sales, and in the long run, it will increase the average costs per sale. A different price policy in the sale process of a product allows customers to decide how much they will pay for the product. Most of the time, an increase in price due to a particular version will exceed the cost of extras, which means that by purchasing of higher-priced versions by customers benefits the company in the long term [44]. Versioning can be used in a large range of sectors. In the digital information age, versioning is even more impactful. Tablets and smartphones are often released in different versions in the consumer technology market, which may feature varying levels of data storage capacity and other options. A newer model, in this case, a version of the same smart-phone may include more up-to-date features compared to its previous version. In such a case, a customer has the chance to decide whether to buy the new version or not. Another example is the companies in the digital information industry. Software companies, for instance, make great use of

versioning in their products. Usually, there are lots of different software that have different versions for different customers. Microsoft Suite has different options for home use, for personal use, and student use. Memberships of different online platforms offer different options for a wide array of customers. Versioning is also applied by the automotive industry to its products. Optional equipment, such as premium sound systems, internet and data services access, and onboard roadside services, can be fitted with the base model of any car [45]. Versioning is simply another form of product classification in that it offers a different type of the same product for the customer. Classification and management of versioning hold importance for the company.

Product variant, differentiation is also a market strategy to make a company's products stand out among its competitors. A definitive good that is bundled with related variants to bring together one distinguishable product is known as a product variant. Just like versioning, product variants also offer different options for customers and keep them interested. Different segments of buyers are attracted by different variants [46]. Product variants generally refer to the different forms of the same product. The product may differ in size, color, shape, flavor, etc. Furthermore, product variants have a great influence on customer behavior. However, it is not the only feature that affects customer behavior [47]. Although product variants may have an influence on customer behavior and their loyalty to the brand, it is far from being the only parameter that affects it. On the other hand, production variants have an indispensable effect on the market. It is still effective in terms of attracting consumers. Variation of the product makes your business more competitive as it focuses on the cost value of the product against similar products on the market, without compromising on the price. It also establishes brand reliability. They also support the company in a saturated market, where more suppliers are offering the same product.

Classification of the different variations of the product matters in being an alternative form of marketing. Even though it is not as distinctive as a newer version, it still has the potential to make a positive effect on sales. Just like the classification of product versioning, the classification of product variants is essential for the company. Although it is mentioned in this paper how making innovations and differentiation in a specific commodity is crucial for the company, this topic is still significant for some simple reasons. Marketing and product innovations are about understanding consumer

behavior. Knowing its target audience and establishing a bond between the brand and the customer will not only help to gain integrity and popularity in the market, but it will also make a long-lasting impact. Methods like product versioning and variating the product are effective in increasing the market value and promoting the company's name.

As the name suggests, Product Ownership means the holding of a products' rights by an individual or a group. The product owner's duty is to maximize the value of the product in question and the work of the development team. Different organizations have different ways of managing the position. Product ownership requires vision clarity, alignment with business strategy, awareness of the process of growth, and the ability to engage with a wide range of stakeholders both within and outside the organization at all levels [48]. Successful ownership of products includes a teamwork strategy that covers a spectrum of skills and experience. Product ownership includes a number of areas of the company and needs several voices to be brought together, including product management, marketing, customer and business advocacy, etc. Product management also includes the management of the classification of the products. The owner should be aware of the advantages that a well-organized item portfolio brings to the game.

CHAPTER III
CHANGE IMPACTS IN PLM

The process of globalization and liberation of the international markets that have been going on for roughly 30 years have had an enormous effect on the overall practices of production, marketing, and manufacturing. These effects include the free flow of market operations, constantly increasing competition, more complex activities of international business, advancement, and development of technology, and the globalization of financial activities [49]. It is no surprise that the constantly evolving state of affairs forces enterprises to make adjustments and adapt to the changes in the global market. The product environment, which is a term referring to the complex interwoven factors that influence all kinds of production and marketing activities, has also been affected by these changes. As it is mentioned, an evolving production environment obliges companies to make certain changes in their organization, production management, marketing techniques, etc. Stark, [50] suggests that there are various dimensions in which the changes occur. These may be macroeconomic and geopolitical changes, environmental and social changes, new products and technology, and the changes that occur within the company itself. Fierce competition in the global market is challenging for many enterprises. Because there are too many alternatives to products, customer behavior is prone to change in such a short span of time. Due to these courses of events, it is essential for a company to have a decent system of change management and methods of product innovation and adaptation. PLM plays a crucial role in the administration of all product-related processes. Before digging into the role of PLM in the changing product environment, we should take a look at the changing factors in the environment briefly. Some major topics of change can be given, macroeconomic and geopolitical changes involve globalization, geopolitical developments, new customer requirements, market mentality, etc. Globalization is probably the most obvious influence on the markets today.

While globalization provides advantages for most companies, like the opportunity of selling products all over the world and international collaborative manufacturing, it also brings challenges. Now that there is more competition than ever, with lots of different enterprises entering the market, which forces companies to innovate and make variations on their products [51].

Geopolitical changes, the most famous of which is the fall of the Soviet Union, affects the business operations profoundly. The end of the cold war led to the globalization of different trade lines all over the world, and the rising influence of China in the global economy also poses a huge threat to western markets. Expanding markets and the emergence of new industries, customer behavior changes swiftly. The observation of customer behavior and adaptation to it is essential in today's market. Apart from the necessities in product innovations and variations, services have also gained importance in the past years. According to [50]: Many consumers also want more services offered along with the brand. It often seems as if the services are more important than the name.

Furthermore, changes in society and the environment also affect the way businesses are done. Constantly increasing the gap between the rich and the poor, urbanization, and the rising participation rate of women in the workplace also changes the way we perceive business in the 21st century. The adoption of technology in business brings ground-breaking developments into the market in all aspects. It seems like there are infinite ways to manage business-related operations. Apart from the benefits of technology in product innovation and variations, it also streamlines data management, which is an important aspect of PLM [49]. So, what kind of effect do these changes have on PLM? PLM is a technology-based, holistic approach to data management. It's a cross-functional system, which means that it deals with the way a company conducts its industry, it deals with its market, it leverages its core competencies.

In such a complex market that is filled with fierce competition between enterprises all around the world, the company must be able to respond to changes in customer behavior and support its products. The company should account for all of the different aspects of manufacturing, marketing, and customer service. From engineering and design processes to marketing techniques and effective customer relations. Because PLM systems work in a collaborative manner supported with technology, it enables companies

to have full authority over the lifecycle of the product. Furthermore, PLM systems reinforce productivity and innovation. Implementation of the PLM approach will facilitate the business' product innovation ability, assuming that organizational change and management of information are collectively performed [50]. Considering the need for good management of product data and innovation and variation, PLM systems have the potential to facilitate change management in the businesses, which is of utmost importance in today's market.

3.1 GLOBALIZATION

Globalization is a phenomenon that has been influencing the world for the past decades. Though it is impossible to point out a specific date, the assumption that the collapse of the Soviet Union had an enormous impact on the liberation of the world markets, is accepted by many. The significance of globalization has been emphasized in many different fields of study. It has a huge influence on politics, culture, and of course, the economy. Globalization of the economy refers to trade, capital flows, and the movement of labor and production. A radical transformation of the economy brings a radical transformation in the attitudes of both customers and the company. This transformation resulted in the market economy generalization, increase in demand, circulation of knowledge, goods, people, and increased efficiency in implementing technological programs [52]. Economic globalization also necessitates global industrial restructuring and readjustment. With the advancement of science and technology and the rise in income levels, all countries' manufacturing systems have also been re-adjusted and updated. Companies of developed countries have started to work beyond the seas and adapted a wider and more collaborative system of production. In recent years, industrialized countries in the West have steadily entered the era of the information economy and have begun to shift to developing countries many labor-intensive industries of weak international competitiveness [53]. As for international companies, because the significance of information management increases all around the world, the management of the product life cycle and the controlling of the product-related data gains importance. The effects of globalization range in a wide variety. Cavusgil [54] suggests that globalization of the markets has at least 5 dimensions: First is the fluid nature of

production and manufacturing. Today, the market operation moves freely to places best equipped to carry it out most effectively and economically. Secondly, another consequence of the globalization of the markets is the increased competition. Compared to decades ago, when only a few multinational companies could dominate international trade, companies from all around the world are able to compete with others in the global market. The third dimension of the globalization of the markets is the proliferation of forms of transactions in foreign businesses. There are far more complex activities of international business, compared to the past. Advancement and development of technology is the fourth consequence that Cavusgil suggests. Electrical systems of business have made a revolutionary change in the way companies conduct business work. The last dimension is the globalization of borrowing-financial activities. By international capital markets, companies fund their growth and expansion. As such, they can take advantage of various interest rates, and currency markets by tapping a wide range of sources of financing [52]. Globalization, and changes in the conventional business activities required developed systems of management, production, marketing, design, etc. In the global market, adaptation to the changes and management of the information flow is of utmost importance. This is why PLM is important for businesses. As barriers between trade locations get more liberating and capital becomes more easily transferable, a need for a globalized production process, which includes the collaborative work of different contributors, has emerged. In the globalized market, companies tend to produce goods in different locations. Generally, production is similar to this example: research and development (R&D) are typically carried out in developed countries, components are produced in different countries depending on their competences, and the final assembly takes place in another country, especially for high-tech goods [55]. PLM gives companies the opportunity to scrutinize the lifecycle of a specific item. The reason why PLM is important for an international company is that it enables companies to act flexibly, gain control, and observe the market. As it is mentioned, globalization of production opened new doors and gave rise to different opportunities for companies. Good management of the product life cycle increases productivity eases the planning and collaboration activities. Coordination of planning and collaboration activities from a single information source is crucial for international companies as these activities include complex

production, design, engineering, and marketing operations [55]. Increased competition is an inevitable consequence of a market that is filled with lots of alternatives. There has been a surplus of productivity since the end of the cold war, which corresponds to the fall of the Soviet Union [53]. Because of this fact, economic globalization has intensified the competition in the international market among various enterprises from different countries. In order to boost their positions and increase their competitiveness in the international market, both domestic companies and those from other countries have been resorting to mergers and acquisitions one after another, which has resulted in tides of industrial restructuring [56]. Increased fierce competition has a profound impact on the way businesses manage their life cycles. According to [57], fierce competition forces enterprises to make changes and rearrangements on the way they manage the life cycles of the products. Businesses should configure and utilize worldwide resources to keep up with the competition. PLM affects the way enterprises act on the market. It enables the companies to interpret the changes in the market and customer behavior. Through this interpretation, companies can make assumptions according to the data that they receive from the life cycle. The situation of a product in different phases of the product life cycle gives general information about how the product is received by the customers, the product's popularity, and its future. A well-managed product lifecycle will also give an insight into how and when the product will be taken out of the market. This information can be used by the company to stand out among its competitors in the global market. In a globalized market that is filled with lots of competitors, customer behavior changes frequently and fast. The success of the product relies on the company's ability to beat rivals to market goods that capture the imagination of consumers with stylish yet properly functional content that performs as needed while being delivered at a price that the market is prepared to pay. In other terms, the goods must be able to fulfill consumer demands. Which are: Timing, function, performance, style, and price [58]. In order to catch up with customer desires, a business must be able to adapt to change and accommodate its demands systematically. Fiercely competitive global market forces companies to make innovations and variations on their products. If not, the company won't be able to sell its service or item. PLM is an integrated, information-driven strategy that speeds the innovation and launch of successful products, helps dispersed organizations, as though

they were a single agency, to innovate, manufacture, grow, support, and retire goods [58]. It is possible today to produce goods with distributed teams across geographies with collaboration tools and process and technology integration solutions. Based on the research strengths and cost-effectiveness, each different team working on different geographical locations can focus on a different part of the product. For example, final assembly may be situated near to the customer, R&D may be situated at a location where intellectual capital is abundant, and repetitive non-core labor may be a situation where manpower is cost-effective, etc. Furthermore, apart from giving the opportunity to outsource innovation, PLM also enables innovation through collaborative mind thought and experience sharing to create innovative solutions and products [59]. Collaborative work discipline will flourish the innovation and variation attempts. For the last 30 years, economic globalization has revolutionized the way we perceive business relations. Constantly increasing competition in the global market requires companies to be aware of the changes and adapt to them. With its benefits in management techniques, innovation, collaboration, planning, data storage, and control, PLM is an ideal system for international enterprises.

3.2 THE EVOLVEMENT of CUSTOMER REQUIREMENTS

It is no doubt that we live in an age in which everything moves at an incredible pace. Together with the benefits of technology, we are now able to simplify and fasten all kinds of operations that we face in everyday life, which also includes business-related operations. The globalization of markets around the world has made a huge impact on how enterprises run activities. Now that there is more competition in almost every market, companies are forced to make innovations and variations on their product and respond quickly to customer needs in order to maintain customer satisfaction. Czarniewski [60] argues that with the spread of new technology, the possibilities of accessing knowledge and the ability to buy goods and services have changed. Consumers have acquired the ability to fulfill their needs more efficiently, easily, and frequently, cheaply. Furthermore, modern consumers tend to request more detailed information about the product they are purchasing. Now that it is easier to track down the product history through UPIs such as GTINs, barcodes, etc., PDM is even more important for companies to satisfy customer

requirements. The fact that the needs of the user or customer change over time are one primary cause of demand volatility. Another reason for changing requirements is that requirements are a result of the contribution of many people, and there are often competing needs and priorities for these individuals.

Requirement management is a multi-disciplinary effort. The effort to satisfy the requirements come from different fields such as mechanics, software, and/or electronics, even marketing, design, and distribution. Because PLM is a technology-based, holistic system that aims to manage all of the lifecycle of the product from a single source of information, it makes it easier, faster, and more efficient to respond to changes in customer requirements. Positive customer experience is an essential part of company success. PLM systems aim to increase the quality of the product, reduce the manufacturing errors, and manage the product lifecycle phases efficiently. The success of the company is strongly connected to product quality. If the company is not able to respond to the changes in customer behavior and adapt accordingly, they will fall behind the current trends in the market. A well-managed product lifecycle enables companies to make changes faster and easier which will lead to positive feedback from the customers [61].

3.3 THE EMERGENCE of GLOBAL PRODUCT

It is no doubt that globalization has impacted the conventional practices of manufacturing and production immensely. The liberation of the economies has made it possible to execute business-related operations in a broader sense. Now companies are able to work overseas and control the marketing, designing, and engineering activities from a single source, even though the activities are run in different parts of the world. Now that it is easier than ever for an enterprise to enter the global market and promote its products, the competition is tense. Changing consumer behavior and increasingly fierce competition has forced companies to come up with various kinds of methods to market their products. Although the term global product is not clearly defined, it roughly refers to a product that is distributed around the world. In addition to being available on the global market, such products are often subject to the same or very similar advertising strategies in specific markets. The distribution of these products is highly linked to the diversity of demand. Culture bound and culture free products affect the marketing strategy for these global products. For instance, the success of a product involving pork meat would

be doubtful in countries with a high Muslim population. For culture-free products, there is no such distinction. These products are fairly recent, thus no connection to cultural factors has yet been established [62].

Global products tend to come in various shapes and sizes. Different colors, sizes, etc. Since the competition is high, companies are forced to make innovations and variations on their products, especially if the product is a global product. There may be a new one for each year, or different global organizations such as the Olympic Games or the World Cup [63]. Global products include consumer products, which are highly popular among the customers, and industrial products, which are civil aircraft, machinery, power plants, etc. Global products have the potential to be served to billions of customers around the world since the market is extended to a broad area. PLM systems are ideal for such organizations that are active in the global market. The fact that PLM enables companies to manage the product data efficiently makes a difference in the way the operations are done. Furthermore, centralized management increases the productivity of the various working teams that are located in different areas, and also reduces the possibility of mistakes.

3.4 GEOPOLITICAL DEVELOPMENTS

In the early 21st century, as a result of several developments, tens of thousands of companies have been able to sell manufactured goods to consumers across six continents for the first time. There are theoretically upwards of a billion consumers for each of these "national goods." Wall Street reached record heights in 2007 when an immense potential for improved revenue and incomes became evident. The new world is not easy to handle, though, and the risks are high [64]. Responding to the various expectations of consumers from a range of nations, selecting the most suitable places for different levels of production, determining what should be multinational or local, implementing appropriate processes and systems, accommodating various national legislation, and efficiently splitting the work between various sites are among the many challenges of the new conventions of production. PLM is used globally to handle the creativity, production, and marketing of global goods. This brand-new market activity enables companies to manage

products anywhere in the world, at any point in its lifecycle: From its very first proposal to its recycling and disposal.

Among these challenges, geopolitical changes play a huge role. Geopolitical changes, such as those arising from the dissolution of the Soviet Union, have an impact on the product climate. The end of the Cold War has driven many nations to take on new positions in the world economy. For example, most of Poland's exports went to the countries of the Warsaw Pact in the 1980s. However, in 2009 Germany had become Poland's largest trade partner. Another example is the relations between China and the US. In the years prior to President Nixon's trip to Beijing in 1973, there was no trade between China and the US. But in 2008, The US had become China's main trading partner [65]. Political transition in China, its enormous consumer opportunity, and its high availability of low-cost jobs have made many improvements. China has emerged as a major commodity and capital goods industry, a dominant producer nation, and an exporter of manufactured goods. For instance, the world's leading steel-producing countries in 2008 were China (about 500 million metric tons), followed by Japan (about 100 million metric tons). The heavy industry in 2014 amounted to about 800 million tons in China, around 110 million tons in Japan, and about 90 tons in the US. China's use of steel grew from around 120 mmt in 1999 to over 500 mmt in 2013. By 2009, China had been the world's largest exporter and the largest automotive market. In 2014, China was second to just the US by the number of billionaires. Russia has been a pioneer in the production of oil and gas. In November 2012, Russia produced 10.9 million barrels of crude oil a day, one million far beyond Saudi Arabia. Russia is the global leader in oil deposits, its Gazprom sold more than $100 billion in 2008. At the beginning of 2007, only Exxon Mobil and General Electric had higher market capitalizations than Gazprom. In 2014, Russia ranked # 5 billionaires globally [69].

India is considered as the leading manufacturer of application & software developers and IS businesses. For example, Infosys, based in Bangalore, became a global IT solutions firm with sales of more than $4 billion in 2009. In 2015, sales approached $8 billion. In 2014, India ranked # 4 billionaires worldwide. The end of the Cold War in 1991 made it possible for several countries that were part of the Warsaw Pact to leave and join

the European Union. By 2010, the European Union had grown to cover 27 countries with a domestic economy of more than 500 million people [66].

Population is also among the factors that affect the potential of a company. Larger populations may signal and opportunity for broader markets. By 2015, China had a population of 1.4 billion, while India had a population of 1.2 billion. More than 1.1 billion inhabitants have lived on the African continent. Indonesia and Brazil had a population of more than 200 million. Pakistan, Bangladesh, Nigeria, Russia, Japan, Mexico, and the Philippines have had more than 100 million inhabitants. These primary future markets present a vast number of consumers with prospects for some multinational commodity suppliers. However, no matter where you are based, some of the nations always seem to be located in remote places [67].

North America is made up of developing nations, such as the United States and Canada. The area is open to the introduction of modern and evolving technologies. Moreover, its solid financial status allows it to invest heavily in the implementation of the new and leading resources and technology to ensure successful market operations. Such advantages allow companies in this field to achieve a strategic edge. North America has the first-ever lead in the introduction of emerging technology, such as smartphones and cloud services. North America is home to a variety of major corporations and hosts numerous international activities. Enterprises are eager to invest in North America. Stable economy, technical advancement, and advanced infrastructure are the factors projected to fuel the growth of the PLM market in North America. Overall, the PLM industry rose to $47.8 billion in 2018 (9.4% expansion over 2017). For 2018, Europe, the Middle East and Africa (EMEA) had 33.4 percent of the PLM market, with the Americas at 37.8 percent and Asia-Pacific at 28.8 percent. The Americas field is expected to rise by 8.3 percent to $26.7 billion in 2023 at the Compound Annual Growth Rate (CAGR). EMEA, and Asia Pacific and Japan (AP) will have CAGRs of 8.3% and 8.6% respectively. EMEA will rise to $24.1 billion and AP will hit $21.3 billion by 2023 [68].

3.5 STANDARDS

There are certain standards that must be respected during the processes of data management. These standards are constantly evolving, and they get more complex. There

are different standards that we can refer to in the context of PLM. Voluntary codes, protocols, or procedures used by organizations to formalize, systematize, and legitimize a very diverse range of administrative practices or tasks are management system standards (MSSs), also called meta standards [70]. There are various functions of these standards which are highly utilized by companies. Examples include quality management, International Organization for Standardization (ISO 9001), environmental management (ISO 14001), the prevention of occupational hazards, and the provision of health and safety regulations in the workplace, Occupational Health and Safety Assessment Series (OHSAS-18000), and corporate social responsibility, Social Accountability International (SA-8000) [70]. ISO 9001, which is a standard that helps to demonstrate what the company does to keep up with customer requirements, is the first version of the document or contract of requirements for systems of Quality Management. Currently, the application of this standard is a requirement for all companies seeking to participate in all markets (domestic, regional, sectoral, European, etc.) [71]. ISO 10303 is an ISO standard for the representation and sharing of product manufacturing information in a computer-interpretable way. It is essential for product data exchange [72]. The ISO 14001 Environmental Management System is a systematic approach that ensures that the production is carried out by taking into account the environmental impacts in every step, from the first stage of the product to the consumer. ISO / IEC 27001 is an international standard that covers the basics of information security. The goal of this standard is to help organizations make the data assets they carry more secure [71]. Petroleum Industry Data Exchange (PIDEX) standards provide a global platform for delivering the process, information, and technology standards that support seamless, efficient digital business within the oil and gas industry and its trading community [73]. Of course, there are still different standards that can be mentioned, but overall, these examples can be considered as some of the standards that are used in different industries. These standards are important in that they enable businesses to manage their strategies and policies to overcome various problems and achieve goals.

3.6 SHAREHOLDER VALUE

Shareholder value is the value enjoyed by a shareholder by the ownership of a company's shares. It is the value provided to the shareholder by the company. Shareholders may manage the company themselves or as in most cases, in case of many shareholders, they delegate this position to managers so that those managers can act on behalf of the shareholders [74]. Management of the shareholder values is of significant importance since it has a direct relationship with the value of the company. The premise of shareholder value is that the stock price will ultimately follow if a business creates value. The aim is to create value and then let that value represent the price [75]. Shareholder value includes managers who prioritize the interests of a single stakeholder, the investor, instead of attempting, as in conventional company theories, to balance the interests of multiple stakeholders or to optimize managerial incentives, as in revisionist studies [76]. Shareholder value is directly linked with the management of the company. Determination and fast decision-making skills, which are highly boosted with the help of PLM systems, are essential for successful organizations. The value of management decisions systems from the fact that these decisions affect every function of the organization. There are lots of different factors that affect managerial decision-making processes.

Undoubtedly, Shareholder value is among the most important factors. Shareholder value both allows top management to concentrate on individual investors and produces a value system, while top management has the opportunity to track the efficiency and the performance of the decisions. PLM offers detailed information about the lifecycle of the product. All the data about the various processes that a product undergoes is controlled and stored through PLM systems. Furthermore, naturally, PLM allows product knowledge users and developers to make informed decisions on product development. PLM will give businesses the opportunity and versatility to innovate, and then generate more value through BOM knowledge management. This, in turn, will enhance the shareholder value, which will lead to a rise in the company's interest [78]. Shareholder value may not seem to function properly as a single concept, but when it is tied with company management, which can be boosted with the implementation of PLM systems, will work as support systems for the company [77].

3.7 LOW COST and LEAN

In a global market that is filled with fierce competition between companies all around the world, cost-cutting is one of the most important objectives of a business. The concept of "Lean Manufacturing" is fairly new in the management strategies of manufacturing companies. Lean manufacturing strategy provides tools to pursue minimize operational cost by the elimination of waste of resources in the manufacturing industry [79]. Lean manufacturing is about reducing waste in any process of production. Furthermore, lean is concerned with customer value. The ultimate objective is to provide the client with perfect value through a zero waste, perfect value production process. Eliminating waste, not in specific processes, but in the whole lifecycle, creates processes that require less human effort, less space, fewer resources, and less time, compared to conventional business systems, to manufacture goods and services at much lower costs and with much fewer defects. There are 5 steps of lean manufacturing, according to Lean Enterprise Institute (LEI):

Specifying the value from the standpoint of the end customer,

Identifying all the steps in the value stream,

Making the value-creating steps occur in tight sequence,

Letting customers pull value from the next upstream activity,

Beginning the process again and continuing it until a state of perfection is reached in which perfect value is created with no waste [80].

So how can lean manufacturing and PLM be utilized together? PLM and Lean Manufacturing are similar in that both enable companies to save time and reduce waste. The use of lean manufacturing techniques decreases overproduction, inventories of work-in-progress, excessive motion and effort, and faulty goods. However, it is only applicable to manufacturing processes. So, an effective and fast response to changes in customer behavior may not be possible. By gathering and associating information about a product during its lifecycle and integrating processes that drive all practical uses of that information, PLM aims to address this delayed responsiveness [81]. As envisaged, PLM collects quality-related information not just from the production cycle, but also from the cycle of use. Implementation of lean manufacturing into PLM systems can enable companies to ensure that all information and product ingredients are well justified and are

of value. Furthermore, companies will be able to save time and minimize errors in the different phases of the lifecycle of the products [80].

3.8 REVOLUTIONARY NEW TECHNOLOGIES

It is of no doubt that emerging technologies have an immense effect on almost every aspect of our life. PLM, being an information management system based on technology, is of course highly affected by such new opportunities. Conventional production techniques and practices are being transformed day by day, with new technological developments. In product development for manufacturing businesses, R&D is moving from analog to digital. Important applications and laboratory systems are being accessible to authorized personnel anywhere, with the help of simple devices and the internet [82]. It is of utmost importance for companies to be able to manage the data flow in order to trace the product and respond to the changes in the market. That is why adapting to new technologies is essential for companies. As new technologies emerge, production processes may get more complex. Many companies have started to adapt to changes in known production practices. In recent years, all of the major PLM developers have made substantial steps to either shore up, add or enhance existing simulation capabilities, with a focus on offering customers a true digital twin [83]. Another example of companies switching to a new and enhanced way of management is digitalized PLM. According to [84], digitalized PLM enables companies to protect intellectual property, provide analytics for precise and current data on product development, provide coordination between designers and engineers in real-time and link all the related disciplines down the value chain, facilitate social media to integrate real-time consumer sentiment during growth, etc.

There are certain trends that may affect the way PLM works today. Connected devices, for instance, will dramatically improve how businesses connect with goods, starting with the opportunity to enter with consumers into the actual physical world. In order for the implementations of such systems to be effective, the whole process should be well-thought-out. Interactive technologies, from mobile phones to websites, mobile apps, and software-as-a-service (SaaS) applications, need to provide the consumer with more realistic, self-directed, bureaucracy-free, and efficient experiences [85]. There are various examples of emerging technologies that signal a change in the PLM system,

including the ones mentioned above. There is no doubt that new ways of management, production, manufacturing will arise with emerging technologies. Cloud systems, connected devices, simulations, etc. A switch to or an integration of technological systems to PLM should be done smoothly if a company desires to keep up with the global market.

3.9 NEW IS APPLICATIONS

The integration of technology into every aspect of production processes has revolutionized the traditional ways of doing business. In a global market that is filled with fierce competition and various challenges, managing information is one of the most important aspects of company success. As products get more complex, enterprises tend to develop strategic steps before they offer a product to the market. Information management is important in that it enables companies to keep track of huge amounts of data. And of course, this is hugely done through software and applications. In order for the different processes of production to go hand in hand, such as design, engineering, promotion, quality, manufacturing, and business, a strong sense of management from a single-center should be maintained [86]. IS Applications are one of the most prominent examples of the integration of technology into business management. These IS are especially significant in the PLM context, since PLM is a data storage and management system based highly on technology. A PLM application is a computer program that is used in the PLM environment to support a specific operation. CAD programs are used to facilitate the activity of product design, for example [87].

Application systems have been playing a huge role in activities related to product marketing, development, innovation, and sales. As the cost of functionality decreased, database management systems increased in value [88]. A Database Management System's primary purpose is to provide a way to store and retrieve both convenient and efficient database information. This activity is also called PDM. The aim of any particular IS is to facilitate operations, management, and decision-making. The information and communication technology (ICT) that an organization uses is an IS, as well as the way in which people communicate in support of business processes with this technology [89]. IS helps to control the performance of business processes. Although there are various types of IS, like transaction processing systems, decision support systems, knowledge

management systems, learning management systems, database management systems, etc, the critical aspect of IS for business is that it can handle tasks which humans are not able to handle. Examples include handling large amounts of information, performing complex calculations, and controlling many simultaneous processes [89]. There are six components of an IS: Hardware, software, data, procedures, people, feedback. The bridge between hardware and people is data. This means that before we include individuals, the information we obtain is just data. Data is now information at that point [89]. There are many different types of IS used in businesses. Data warehouses, enterprise resource planning, search engines, global IS, office automation, etc. can be counted as the different types of IS. Innovation in industry and IT in today's companies are two significant drivers of evolution. They lead them to take new forms, to re-engineer their business processes and to upgrade technology, and to create new types of inter-organizational and networked IS as well as to provide online services [90]. Just like every other convention in the business and marketplace, IS also undergoes certain changes and evolves into something more different and complex, as new technology creates opportunities for developers. The development of IS can take various forms: the integration of new market or custom-made components, the development of services on top of the existing IS the creation of interoperability between two or more IS, etc. The 1990s saw a huge development and change in the IS. Resource for Manufacturing Planning (MRP2) grew to Enterprise Resource Planning (ERP). They covered more and more of the product lifecycle as the reach of MRP2/ERP applications was expanded. CAD and PDM features became a commodity in the 1990s [88]. Any shift in the organization, business operation, or regulation of the company inevitably involves a chain of developments in its IS and information services. Actors in charge of IS evolution steering must take crucial decisions that can be catastrophic for the company's business and reputation IS [90]. The history of IS is now very long. The Manufacturing Resources Planning (MRP) programs were implemented in the late 1960s. This software, running on a mainframe computer, has provided businesses the ability to control and make the development process more effective. In the later decades, the introduction of Personal Computers (PC) has made a revolutionary impact on IS. During this time, common uses for the PC included word processing, spreadsheets, and databases, making it suitable for data storage. These early

PCs were not linked to any kind of network; they stood alone as islands of creativity within the larger organization for the most part. In the 1980s, Companies have started to see the need to link their machines together as a way of communicating and sharing resources. Software companies began to develop applications that allowed multiple users to concurrently access the same data. This grew into interacting software applications, with at this time the first real widespread use of electronic mail emerging. Computers had started to be seen as a tool to collaborate in a company or an organization. The first ERP systems were developed and run on the architecture of the client-server during this period. An ERP framework is a centralized database software program that can be used to manage the entire business of a company. The advance of the World Wide Web (WWW), in the early ’90s, became the starting point of the internet as a channel of information flow between business teams. All of these groundbreaking changes made a significant impact on the evolution of IS [91]. Especially the WWW made it possible for many activities to be carried out faster and/or at a lower cost. It enabled information to be transferred faster. Engineering, for instance, sketches can now be sent by e-mail or on the Web, rather than by post. Product requirements can be gathered on the Web via questionnaires. It is possible to configure and order cars and other products on the Web. Product Development data can be shared between workers on multiple sites in a Web-based project workspace. Developers at various locations can together review product designs [88]. In the global market today, every business, no matter where the business is based or how big the corporation is, in competition with some other. Customer behavior constantly changes, and it changes fast. To keep in track with the global trends, a business should be able to handle every aspect of the product life cycle studiously. Only businesses that are able to keep up with innovations and adapt to the situation by making changes in their business processes can expect to maintain their performance at the level required and remain competitive. The success of any business is directly linked to the level and quality of IT used in the company and the ability to correctly use that information [88]. In short, a well-implemented IS is one of the major factors that influence a company's success in the global market since it supports an enterprise in every step of the Product Life Cycle. PLM, reinforced with IS, is the key element of a proper information flow and administration.

3.10 BUSINESS PROCESS RE-ENGINEERING (BPR)

Business Process Management (BPM) is a crucial concept for company owners. There are so many different layers of process management that have a huge impact on the end product and naturally, on the general perception of the company by the consumers. Strategic management includes the development and execution of the key objectives and initiatives taken on behalf of owners by the top managers of a company, based on resource consideration and an examination of the internal and external environments in which the organization operates. The current marketplace is extremely unpredictable, evolving, and competitive. In such a business environment, access to and management of real-time data is of utmost importance. Business Process Change (BPC) or BPR is considered the most essential challenge for system integration. BPC refers to an organizational strategy-driven effort to enhance and (re)design business processes to gain a competitive performance advantage through improvements in the relationships between management, IT, organizational structure, and people [94]. In order to boost customer experience, reduce operating costs and become world-class rivals, BPC was intended to help companies radically reconsider how they do their job. BPM theory is something that has been constantly revised and re-evaluated since the nature of the competitive business world compels companies to do so. Business processes are the definitive methods to facilitate business operations according to the organizational rules and policies. It is important to adjust its main drivers, which are method, people, technology, and information flow among the processes, people, technology, and flow of information in successful system integration [93]. Re-engineering demonstrated a comprehensive emphasis on business priorities and how systems apply to them, supporting full-scale process recreation rather than iterative sub-process optimization [95].

What is special about BPR is that it not only offers innovations on an already-built system, but it also tries to make radical changes to it. It involves essential changes in not just only partial aspects of engineering processes but on the core aspects too. In order to fully grasp the concept of BPR, we should take a look at what “Process” refers to.

As suggests, there are many different ways to define business processes. It generally refers to a collection of various activities or tasks carried out by an organization in a certain order and utilizing certain resources in order to fulfill the goal or the object of

its life. Because all business processes are affected by various parameters such as output quality, speed, cost, added value, and the like, it would not be wrong for us to conclude that they are crucial for maintaining competitive advantage. Therefore, tracking and evaluating them is key to eradicate any disadvantages in their output before endangering a company's survival [96].

New technologies are the most important change factor in the re-evaluation of the business processes. Emerging technologies are making profound changes in the business processes that we know today. Technology expresses itself in tiny details of everyday business activities, from shifting customers' tastes to reshaping the manufacturing and selling of products. In such an ever-changing environment, re-assessment of the business processes are inevitable, and they should be. Company owners or entrepreneurs should be aware of the fact that our contemporary world is bound to change almost every minute. This ever-changing nature of the 21st century compels companies and business-owners to observe and adapt to the new trends in the market and especially in the business processes.

Frederick Winslow Taylor, who was highly influenced by Henry Ford and his business, was an American engineer who studied the ways of increasing industrial efficiency. Taylor was one of the Efficiency Movement's intellectual founders, and in the Radical Period (the 1890s-1920s), his theories, narrowly conceived, were highly influential. In1911, in his book The Principles of Scientific Management, which was voted the most influential management book of the 20th century by Fellows of the Academy of Management in 2001, Taylor summed up his productivity techniques. He emphasized the importance of such concepts as simplification, systematic experimentation to find the most efficient way of working, and for control systems to assess and reward the output. His book became a phenomenon, and his ideas were adopted by many global companies in the succeeding years [97].

Aforementioned, technology is such a great influence on the business processes that the way the business is done today is quite different from that of the 1950s or even 2000s. Softwares and online customer services have simplified and eased the way we produce, design, and market. It also accelerated the pace of the processes, undoubtedly. By face-to-face encounters and mail, a process that took several weeks some years ago can now take a few seconds with computer keystrokes. From a manufacturing point of

view, technological acceleration has pushed businesses to satisfy the demands of their customers more quickly and provide the processes with the requisite resources. Means of communication have become widely accessible and utilized by many companies around the world. The availability of global economic data and internet video conferencing makes it possible for corporations to conduct business and opening a business on another continent is almost like opening one in the neighboring region. Through the improvement of transport, communications, and logistics, technology has promoted convergence and interdependence [98]. All these developments revolutionized the way we thought about business processes.

At this point, the importance of BPM should be emphasized. As the name suggests, BPM refers to the analysis, design, implementation, and continuous improvement of organizational processes. According to the article in, BPM is characterized by two concepts:

Process Improvement,

Process Reengineering [99].

Michael Hammer's "Reengineering Work: Don't Automate, Obliterate" and Thomas Davenport and James Short's "The New Industrial Engineering: Information Technology (IT) and Business were highly influential for BPR in that they constituted a milestone in the perceptions of business processes. These theorists emphasized the comprehensive nature of business processes. In an integrated manner, work designs, organizational frameworks, management processes, everything relevant to the operation, must be refashioned. In other words, in many parts of the company, reengineering is a massive undertaking that mandates transition [100].

Hammer called for radical changes in the business processes. By famously arguing that larger companies had got more inefficient by growing larger and more specialized. Hammer stressed an unusual point in the BPM. There were 2 solutions to this problem, according to Hammer, Davenport, and Champy: First: The conception of the processes would have to be complete. They should be referred to as comprehensive entities that stretched from the initial order to the delivery of the product. Second: Much of their focus was focused on improving how people worked in the 1980s, while BPR placed much of

the emphasis on using IT more efficiently in the 1990s and on automating processes whenever possible [101].

Software technologies played a crucial role in the development of BPM and redesign. Some businesses have used software applications to automate business operations, called workflow systems. Early workflow systems, in theory, govern the transfer of records from one worker to another [101]. Work is handled. Workflow management technology is a technique for automating, incorporating, and handling jobs. This includes flexible process modeling, simulation support for' what if', real-time status tracking, and performance assessment capabilities that can significantly enable a company to re-engineer its business processes [102].

ERP systems are another kind of software that emerged in the same period. ERP refers to a category of software used by companies to handle day-to-day business activities such as accounting, procurement, project management, compliance and risk management, and operations in the supply chain. A full ERP suite also includes management of enterprise efficiency, software that helps schedule, budget, forecast, and report on the financial results of a company [103].

Adoption of these various kinds of software that enables companies to manage their business processes more effectively signaled a significant change in the industry. However, the utilization of these software in business was much different from what Hammer and his contemporaries advocated. At the time, Hammer and his contemporaries called for a total reconceptualization of the business processes in a holistic manner. To provide the company with the best possible new business process, everything had to be reconsidered and redesigned. On the other hand, the workflow and ERP approaches focused on automating existing processes and replacing existing legacy systems, departmentally focused, with new software modules designed to work together. These systems were narrowly focused and heavily depended on IT individuals to put them in place, rather than radical redesigns, they provided small-scale improvements [101]. As mentioned before, adaption to the changes is one of the most important traits of a business. The 21st century brought significant changes to the notion of BPR. The 21st century started slowly for businesses. But by 2002, people had started to become aware of the opportunities that the late 90s offered with its new technologies, with respect to BPM.

Many people employed in IT realized that a variety of diverse technologies built in the late 1990s could be combined to create a powerful new approach to promote the everyday management of business processes. “BPM: The Third Wave by Howard Smith and Peter Fingar” was an important book that reflects the mindset of the companies. They suggested that businesses combine systems for workflow, applications, integration frameworks for apps, and Internet technology for the development of a new form of software application. In essence, a Business Process Management System (BPMS) will organize the regular operations of all staff and software systems for the new software. 2003 saw a significant increase in the usage of BPMS products. The BPMS tools have become much more effective and versatile as each new technology has been brought to market. In 2002, the United States held no BPM conferences. In2012, the nation had a dozen BPM gatherings, and the first major international BPM conference just took place in China [101].

Our contemporary world necessitates a transformation in the business. This necessity is not a definitive one, though. Constantly evolving trends force companies to always adopt new concepts almost in every aspect of production, engineering, marketing, etc. Peter Fingar, an expert on BPM and the executive partner in the digital strategy firm, the Greystone Group, argues that: ”We are on the verge of a global war of creativity, powered by competition based on processes. As an example of one of the first businesses to actually sell time, he used FedEx. The next frontier of market advantage is organizational change.” He further explains his argument by giving a specific example: “He states that by mastering the methods for time-based competition, businesses can now transform their activities. Internet networking using and leveraging BPM is a great example. By making significant systemic changes, many businesses have changed the way they do business.” [104].

According to Fingar, BPM also plays a huge role with respect to the customer’s relationship with the company. He defines it as how to deliver value to customers. He says that:” BPM takes all the different islands of expertise, data, business rules, and applications that represent key business activities and unites them into an IS that is open to ordinary business people, to help them manage the business in an easier way.” BPM, which also includes the rethinking and the redesign of such processes, has a strong connection with customer service. Despite the widespread acceptance as a declarative end-

goal in BPM of greater customer loyalty and enhancement of customer relationships, most academic and technical initiatives aimed at improving business processes concentrate on improving intra-organizational processes. There is a new way of melding BPM and customer service into each other: “ Gersch et al.(2011) indicated that a good approach to integrating the preferences of customers is the combination of BPM with service blueprinting. Because BPM is a management discipline aimed at designing and managing processes, and service blueprinting is a method that helps to gain an understanding of customer-related processes, combining them to maximize service interactions is also an essential step in making profitable customer orientation and servitization.”[105].

BPC, or reengineering, is a crucial concept for the management of the processes in general. As a holistic concept, BPR enables companies to have full control of each of the business-related operations through new technologies, in this case, they are various software utilized by companies. The adoption of technology has made significant changes in the management of business processes. BPC, being a management strategy, is of utmost importance in an age in which the information flow is unstoppable.

Other change impacts are in PLM:

Regulation and Compliance Deregulation

Changing Business Models

New Company Structure

Market Mentality

Traceability

Education and Training

Workforce Age Distribution

Free Trade

Corporate Theories

Intellectual Property Management

The Aftermarket

Improved Travel

Transport and Telecommunications

Communities

CHAPTER IV
CHANGE MANAGEMENT THEORY & PRACTISE IN PLM

An ever-changing environment of business requires companies to adapt to changes in order to solidify their position in the market, even more so, if they are to really expand [106]. When it comes to the current market, changes are unavoidable. Growing global competition and constant development of technological resources enables us to conclude that the dynamic nature of the market won't undergo any changes in the near future [107]. Some writers say that transition never begins and it never ends [108]. That is why many organizations are now in an effort to adapt to the changing nature of the market.

In the field of IT solutions, creative technologies, and globalization, the external world and its rapid development continuously force businesses to make changes. J. Skalik argues that changes are dually established in the factual and active context. They show a state of something entirely different in the factual context. They are a mechanism itself in the active sense, leading to the introduction of this new state [109]. The two definitions are connected, that is why the new points out the way the change process should be managed. The basic typology of changes represents: Strategic, structu-ral, process-oriented and people centered changes [110]. Because strategic changes require the alteration of the fundamental perception of doing business, most of the time they involve the whole company. Structural changes come into the category of any changes made to the hierarchy of authority, processes or management structures and to other management issues relating to the company as a whole or as a part of it. Process-focused changes are concerned with the production processes and their re-engineering activities in order to optimize the workflow and increase productivity. Lastly, people-centered changes are concerned with revising the behaviors, abilities, or attitudes of the employees [111]

4.1. THEORY “O”&”E” of CHANGES

Theory E is an economic value-based change management strategy. Theory O, on the other hand is a change management strategy based on organizational capability. Both being solid models of change management, they facilitate the achievement and development of some of the management goals, either explicitly or implicitly. However, they also have some costs, many being unexpected ones.. Theory E change strategies are the most popular ones. Shareholder value is the only valid indicator of organizational performance in this "hard approach to transition. Change usually incorporates an emphasis on economic incentives, substantial layoffs, downsizing, and restructuring. Among businesses in the United States, where financial markets force corporate boards for rapid turnarounds, E change strategies are much more popular than O change strategies. The case of William A. Anders can be shown as an example. When he was brought in as the CEO of General Dynamics in 1991, he aimed to maximize the economic value, whether the remedies were challenging or not. Throughout the next three years, Anders managed to reduce the workforce by 71,000 people-44,000 Through the divestiture of seven firms and the layoffs and attrition of 27,000. Popular E techniques were adopted by Anders. Managers who subscribe to Theory O believe they could harm their organizations if they were to concentrate solely on the price of their stock.. The purpose of this "soft approach to change is to improve corporate culture and human capacity through individual and organizational learning, the process of improving, seeking input, reflecting, and making more improvements. Companies from the U.S. that use O strategies- one of them being Hewlett-Packard, when their performance flagged in 1991, typically have solid, long-held, commitment-based mental agreements with their employees.

Managers in such companies can see the risk of breaking these kinds of commitments. Asian and European companies tend to adopt O changes since they also have a close relationship with their employees.

Very few businesses only adopt a single theory. Most companies aforementioned tend to use a mixture of these. But executives all too frequently continue to apply E and O theories in combination without addressing the inherent contradictions between them. This instinct is directionally appropriate to merge the methods, but theories E and O are so different that they are difficult to handle at the same time, workers mistrust leaders who

vary between caring and cutthroat corporate conduct. However, our research argues that there is a way to resolve the tension in such a case, so the companies can satisfy their shareholders while constructing viable institutions. Companies that can manage to find the balance between hard and soft strategies to change can reap big payoffs in profitability and productivity. Those companies are much more likely to achieve competitive advantage in the market. Furthermore, they will be able to reduce the anxiety of corporate restructuring that affects many people. In this article, we will examine how the conflicts between E and O strategies were successfully resolved by one organization. But before we do that, we should take a look at the differences between these theories [112].

4.2. CHANGE PROCESS THEORIES

Most organizational scholars would agree that change over time in an institution is a variation in shape, consistency, or state. The subject in question can be an individual's job, a workgroup, a strategic business unit, the overall organization, or an industry. Such changes in any subject presents itself in alterations in layered forms across time. Most of the organizational change literature focuses on the essence of these discrepancies, what caused them, and the implications. There are many useful distinctions in the literature on change; expected or unplanned, incremental, or radical, evolutionary or transformative, emergent or realized, induced or autonomous, recurrent or unprecedented and more. [113-116]. As is evident from even this short list of distinctions, describing how and why change in organizations has been a crucial and ongoing pursuit for management scholars and other fields of social science [117-118]. Van de Ven and Poole model a typology of this literature by classifying change processes along two dimensions: mode of change and unit of change.

In comparison to changing sequences prescribed a priori by deterministic or probabilistic rules, the Mode of Change distinguishes between changing sequences that are constructed and emerging. Unit of change, on the other hand, distinguishes between change processes that involve the development of a single organizational entity contrary to processes that involve interactions between two or more entities. Through cross-classification of these two dimensions, Van de Ven and Poole identified four ideal theories that are commonly used to describe the reasons and the methods of the changes - life cycle,

teleology, dialectics, and evolution. (Figure 1). These four hypotheses are reviewed here because they serve fundamentally distinct bases for strategic reform. To understand the processes that unfold, each theory focuses on a different set of change-generating mechanisms and causal cycles.

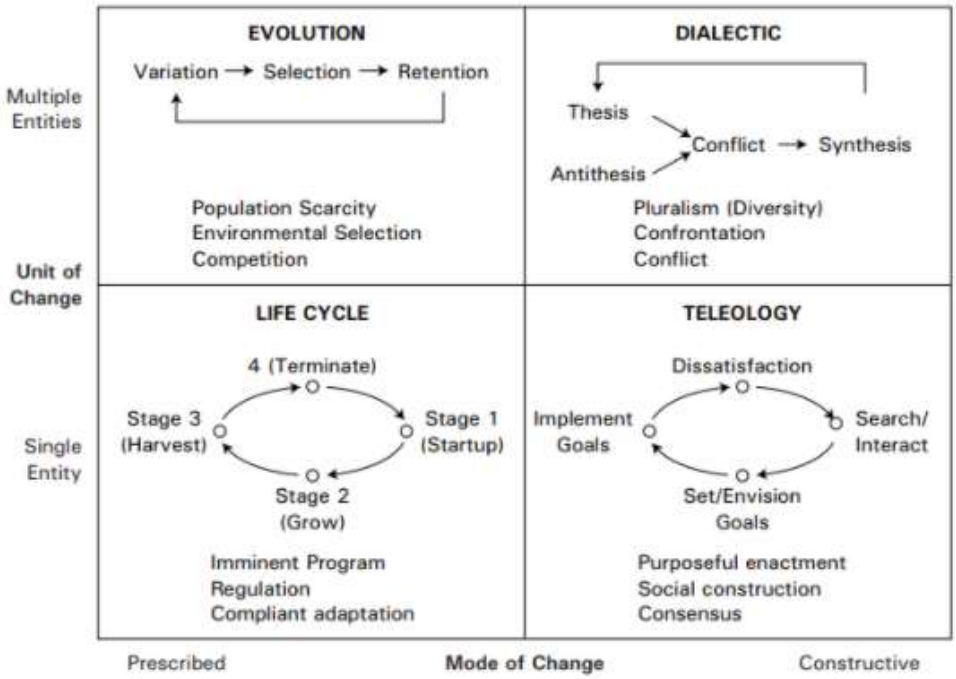

Figure 1 : Process Theories of Organizational Development and Change **[119]**

Teleological theories believe that organizations are purposeful and adaptive, and that transition is present as an unfolding period of objective creation, execution, assessment, and learning. Because learning can lead to the rearrangement of goals or the actions taken to achieve them, learning is essential.

Dialectical theories concentrate on competing goals between various interest groups and clarify the confrontation and balance of power between the opposing entities in terms of peace and change.

According to Lifecycle Theories, change is a progressive process that develops through fixed chains of phases that are cumulative, in that in the outcome, the effect of each phase can be observed. Furthermore, each stage is a necessary precursor for the next and they are highly related to each other.

Evolutionary theories argue that change progresses through a continuous sequence of variation, selection, and retention. Variations only occur and are thus not purposeful, but are then chosen on the basis of the best match for the resources and environmental demands available. Retention refers to the continuity and preservation by the forces of inertia and persistence of the organizational structures that emerge from these variations [119].

4.3. ORGANIZATIONAL CHANGE MANAGEMENT MODELS

Cameron and Green talk about nine models of organizational change, which are developed by some of the prominent authors in the field. These models represent methods of analyzing organizational change and therefore are essential in answering the sub- and research questions [120].

Lewin's three-step model, being one of the oldest models of organizational change, was already developed in 1951. Lewin suggested that organizational change in general has three steps. The actual state of affairs is unfrozen in the first phase. This phase, therefore, involves identifying the current state, exposing driving, and resisting forces to change and imagining a desired end-state. The second step requires shifting to a new situation. This step is actualized through the involvement and cooperation of individuals. In the final step, new policies are established, success is rewarded, and new standards are introduced. The new state is then stabilized and refrozen [121].

Kotter's eight-step model is another renowned model of organizational change. He introduced eight essential steps for making change happen. These are: establishing a sense of urgency, forming a powerful guiding group of people, creating a vision, communicating this vision, empowering others to act on the vision, advertising short-term visible improvements, rewarding people who work towards the defined vision and finally making sure that the change sticks by ensuring everyone´s understanding that their new behavior leads to success. Since the eight-step model of Kotter is a straightforward method, it comes under the same category of organizational change management models as the three-step model of Lewin since they both treat change as possible to prepare for change [122].

4.3.1 K. Lewin Change Management Model (1951)

The method of change management models can be used when implementing improvements for a wider organizational spectrum. Among all these models, the most simplistic one is the one developed by Lewin. He identified three stages of change:

Unfreeze,

Change,

Refreeze.

Although this model developed in1951, is the simplest and oldest, it provides the basis for more models that either expand the steps with specifics or extend the step with an organizational sense [111].

4.3.2. Kübler-Ross Five Stage Model (1969)

In her book" On death and Dying" tiling it as "Phases of Grief", Elizabeth Kubler-Ross introduces her change management model. The stages in the model refer to rather emotional frameworks that include,

Denial,

Anger,

Bargaining,

Depression,

Acceptance,

Commitment [123].

4.3.3. The McKinsey 7-S Model (1977)

The McKinsey 7-S Model was developed by Tom Peters, Richard Pascale, and Robert Waterman Jr., while McKinsey& Company employees. The model analyses seven facets of the company or project team, outlining the improvements to be made. The 7 S Model consists of:

Strategy,

Structure,

Systems,

Skills,

Staff,

Style,

Shared Goals,

Strategy includes transitioning, as defined by the priorities, the company from the current role to the new position. The structure clarifies and defines the tasks, duties, and accountability relationships [125]. Systems are the company or project team's standardized processes. They refer to the management control systems, performance measurement/reward systems, planning, budgeting, resource allocation systems, and IS. Systems influence actions because they are the structures that affect the resources available to a given individual, as well as the processes by which people are rewarded and groups evaluated [126]. Skills are the ability of workers and team members to do the work of the company or project team. Skills are the model element, and the staff acquires these skills. Furthermore, this element analyzes the ways in which businesses hire and retain employees into the organization or project team. Finally, shared goals act as a key point of organizational beliefs and they also help employees to comprehend the organizational purpose and how it will influence the internal and external environments [124].

4.3.4. Grainer Change Management Model (1977)

Grainer defines 7 phases of change in his model,

Pressure on top management,

Intervention of top management,

Diagnosis of problem areas,

Intervention of new solutions,

Experimentation of new solution,

Reinforcement of positive result,

Acceptance of new practices [127].

4.3.5. Bullock Batten Change Management Model (1985)

In the beginning, the four-step model of the organization was thought of as a whole and not as a set of elements that turn attention into interpersonal relations during change implementation. Bullock and Batten define the 4 phases of change explorations:

Awareness of change process,

Planning-aim definition,

Action-designing rules of change management,

Integration-introducing new behaviors.

Because their planned change model depicts the four stages of planned change, it is comparable to the models mentioned before. First, exploration involves identifying the need for change and acquiring the necessary resources for change. (e.g. expertise). In the next phase of planning, key decision-makers come up with a plan for change that depicts a series of actions needed. The action stage involves the actualization of the actions compared to the plan made. Furthermore, this stage includes the feedback mechanisms which allow the replanning of the actions in case things go wrong. Once the plan for change has been fully implemented, the fourth and the last stage of integration begins. In this phase, the change is lined up with other areas of the organization. In addition, the transition is formalized through policies and rewards [128].

4.3.6. Beckhard and Harris Change Management Model (1987)

Beckhard and Harris' (1987) model of change is a more dynamic model compared to the others. This formula is a way of explaining the process of transition and defining variables that need to be in place so that change will eventually occur.: C = (A x B x D) > X Where C = Change, A = Level of dissatisfaction with the current state, B = Desired end state, D = Practicality of change, X = Costs of change. As we can conquer from the formula, the factors A, B, and D should outweigh the cost (X) in order for the change to occur. Therefore, "if any person or group whose commitment is needed is not sufficiently dissatisfied with the present state of affairs (A), eager to achieve the proposed end state (B) and convinced of the feasibility of the change (D), then the cost (X) of changing is too high, and that person will resist the change" [121]. In addition, it becomes apparent through the multiplication of the formula that if one of the variables A, B or D is zero, the end product C will also be zero and it is not possible to resolve resistance to change. As a result, it can be said that A, B, and D cannot compensate for each other, but all factors need to have weight [129].

4.3.7. Carnell´s Change Management Model (1990)

The change management model (1990) of Carnell also takes administrators into consideration. It proposes that specific management skills are crucial for the effective management of change. By encouraging people to learn and by maintaining a risk-taking environment, managers should be able to handle transitions effectively. In addition, by setting up a more adaptable culture by for example, more local autonomy, a manager can deal with organizational cultures. Lastly, a compromise and acknowledgment of various agendas will enable the manager to control organizational politics efficiently. Only managers with these three talents will be able to create an environment in which risk-taking, innovation and improved results can be applied [130].

4.3.8. Bridge's Change Management Model (1991)

Bridges´ managing-the-transition model was introduced in 1991. It does not concentrate on planned change but rather concentrates on the process of transition. Through this, he describes change as letting go of the past and adjusting to new actions. Therefore, the separation of the mechanistic functional changes from the human emotional processes of adapting to change comes into question. Change can be prepared, it is believed, while change is psychological and thus more complex. While Bridges' model helps to explain the emotions of individuals at each phase of the change process, it also develops beneficial activities that should be performed in each phase. The transition process has three phases.

Called ending,

The neutral zone,

New attempts,

Called ending is the first one. It is needed to end what used to be before starting something new. It is important to recognize who is losing what and to accept these losses publicly to mark the endings. The neutral zone is the next phase. In this phase, motivation may decrease as the anxiety increases. Bridges emphasize that managers should make people perceive the neutral zone as some sort of creative process and a time for establishing temporary structures. New attempts should be introduced in the next stage. Four key elements are essential for people in this stage: A purpose behind the change, a

picture (vision) of what the new organization will look like, a step-by-step plan to get to this desired state and participation in the outcome. The new beginning is framed immediately after people start to feel emotionally committed to engaging in something new. Something important to point out is that endings tend to be longer for people who are in the lower parts of the hierarchy. Managers, who have already reached a new beginning, should therefore be tolerant of the transition of their employees.

4.3.9. Kotter's Change Management Model (1995)

The eight steps for changing your organizational areas are as follows, according to Kotter:

Build a sense of urgency around the need to achieve change; if they do not feel the need for it, people will not adjust;

Form a leading coalition-assemble a power-energy group and control the entity to lead the change;

Build a mission and strategy-create a vision of what the transition is about, remind individuals why the change is needed and how it can be accomplished;

Express the vision of change: remind people why, when and how the changes are, in every possible way and at every opportunity;

Encouraging broad-based action-involving individuals in the attempt to improve, allowing people to care about the changes and how to accomplish them rather than worrying about them.

Why do they not like the modifications and how to protect them?

Produce short-term gains-it is important to see the changes emerging and to appreciate the work performed by individuals to accomplish the change;

Sustain gains and drive more change-create energy for change by building on changes, invigorating people by changes, cultivating people as agents of change; and

Anchor modern business culture approaches, which are essential to long-term sustainability and institutionalization of reforms. I do not do so, and improvements made by hard work and commitment may fall away with the propensity of people to return to the old and easy ways of doing things [132].

4.3.10. Nadler and Tushman's Congruence Model (1997)

The model of congruence of Nadler and Tushman seeks to explain as it affects the dynamics within an organization. Internal and external inputs (resources, policy and environment) are translated into outputs in this model (individual, team and organizational behavior).

The method of change is hereby evaluated according to an organization's unique context. An organization contains four elements, including the job (daily activities), the staff (skills of people working in the organization), the structured organization (organization processes and policies) and the informal organization (unwritten activities like values and norms). These four components depend on each other and the greater the congruence between them, the better the efficiency of the company is. As a consequence, the model stresses that it is necessary to pay attention to all four components at the same time, because only then can a reform effort succeed. The model of congruence for an enterprise is a method of change management that evaluates an organization's success based on how it functions as a structure. The business is broken down into distinct components, and the concept of congruence analyses those elements and aims to strengthen the company by optimizing each aspect. To understand how the model of congruence operates, it is important to understand the elements that make up the overall capacity of an organization to perform [133].

4.3.11. Senge's Change Management Model (1999)

A systemic model for sustainable transition was developed by Senge (1999). This model is thus distinct from, e.g. Kotter's eight-step approach, since it does not concentrate on the early stages of transition formation, but also explores the continuity and long-term organizational change renewal facets. The four major recommendations of the authors for this are:

Initiating (start small),

Maintaining (grow steadily),

Redesigning (do not schedule the whole case ahead),

Rethinking reform (expect difficulties) [134].

4.3.12. Stacey and Shaw's Complex Responsive-Processes Model (2001)

The complex-responsive-processes model (2001) of Stacey and Shaw has an important notion that complex transition is viewed as uncontrollable. As a result, the writers do not seek to address the conventional issue of how to handle change, but instead concentrate on managers' involvement in the change initiative [135]. In dynamic transition, there are three main tasks of leaders:

Improving people's thought about how to accomplish goals,

Fostering input and flow of information,

Concentrating the attention of people on gaps between the present and the ideal state [120].

4.3.13. ADKAR Change Management Model (2003)

In comparison to the transition itself the ADKAR paradigm emphasizes on individuals responding to transition. How a person encounters the shift is sequenced by the ADKAR model. After defining a change, the ADKAR life cycle starts. There is a structure and series from this initiation stage for handling the human side of change. The acronym stands for the five priorities the model strives to achieve. They are:

Consciousness

Ambition

Know-How

Capability

Strengthening

Knowledge is where personnel are told of a need for improvement within an agency or project team. Determining the degree of improvement for a given project is the primary challenge at this time. The ambition of the workforce and project team needs the drive to take part in the transition and the willingness to make appropriate improvements. Employees therefore require knowledge of how to adapt and what the transition entails. ADKAR continues to be able to incorporate improvements on a day-to-day basis, which are the qualities required. To maintain and manage improvement in the organization or project, strengthening is then needed [135].

4.3.14. Nudge Change Management Model (2008)

Compared to helping people adopt modern systems, innovations and follow new methods, improvements in corporate structures, adaptation of new technologies and operating strategies are comparatively simpler. Employees are the most critical force behind any change initiative's progress. It is crucial to consider why human nature changes and what motivates us to embrace change in order to get people ready for change. These questions are posed by hypotheses and models of behavior modification. These models direct us to what influences impact human actions and what induces changes in human behavior. Nudge theory is the most contemporary and important model of behavior change among multiple behavior change models. The Nudge theory is a principle of behavioral science developed by Richard Thaler and Cass Sunstein in the book Nudge: Improving Decisions About Health, Wealth, and Happiness... Instead of asking the workers what to do, the decision landscape is structured so that employees themselves choose the appropriate improvement.

The theory is a reasonably slight improvement in legislation that allows individuals to make choices that are in their general self-interest. We will make it easy for them to choose what is right for them, their families and culture by learning how people think. It's not about financially penalizing persons if they don't behave in a certain manner. It's about making it easy for them to make a particular decision [131]. There have been several changes in the way customer behavior is evaluated over the last few decades. One of the most current theories on customer behavior is known as the principle of nudge [136].

4.3.15. Armenakis and Harris Change Management Model (2009)

A method for managing organizational preparation for the transition was proposed by Armenakis and Harris. This model is made up of five main components and seven tactics aimed at building ready for the transition.

The five elements are:

Inconsistency

Effectiveness

Suitability

Principal assistant

Private valence.

The first part, inconsistency, suggests that the workers consider a discrepancy between the present situation and the desired future situation. Effectiveness refers to faith in the capacity of one to complete the process of transition. The third factor is suitability, which refers to the belief that the expected transition is the right option for a desirable future condition to be accomplished. The fourth primary factor, main assistance, relates to the help offered during the transition process by the employees. The fifth one is the personal bravery. The question in this segment is 'What's in it for me?' For the change receivers to be able to stick to the change process, they must have at least in part, a constructive response.

Also, in a framework to build preparation for the transition, there are seven techniques for communicating and strengthening the above five main message elements.

Knowledge control,

Persuasive contact,

Formalization activities,

Dissemination methods,

Human resource practices,

Rites and ceremonies,

Active engagement are these strategies [137].

4.1.16. Ackerman and Anderson's 9 Stage Change Management Model (2010)

The target model of the Ackerman and Anderson method will direct transition leaders from inception to execution, even beyond design to incorporate the new state into operations to produce the full range of outcomes originally planned. Leaders need to have a model of the process of change that extends their thinking and conservation of both internally and externally transition dynamics, one that allows them to observe what is happening in their life development and generate debate about it There are nine phases in the models that are:

Prepare the lead for the modification.

Creating devotion and potential for corporate vision.

Assessing the condition to evaluate the specifications for the template.

Design the state needed.

Analyze the effect.

For execution, prepare, and coordinate.

Implement the modification.

Celebrate the new state and incorporate it.

Learn and correct course [138].

4.1.17. Cummings and Worley Change Management Model (2015)

They introduced a model containing 5 activity measures to obtain successful change management:

To inspire improvement,

To create a vision,

The development of policy assistance,

The management of the change,

Maintenance of momentum.

The first phase in the activity, motivating progress, entails building preparation for change and supporting the resistance of the change receiver to change. Step two, creating a vision, is a leadership role in which the rulers are responsible for creating the why' and what of the next transition. To enforce the reform and discourage people and organizations from preventing it, leaders need to obtain approval from workers during the third process of building political support. As a fourth step, leadership needs to establish an activity schedule for the actions of transition.

Furthermore, it is the responsibility of the management to prepare how to keep workers involved and develop a leadership framework to direct the company through the expected transition. Sustaining momentum, the fifth activity entails offering tools for progress, maintaining a support structure for change managers, learning new skills and competencies, improving new habits, and keeping on track to achieve the change process [139].

4.4. ENGINEERING CHANGE MANAGEMENT (ECM)

Engineering changes (EC) such as new product development, tend to require detailed planning and management through a formal process widely known as ECM. Each EC aims, by product redesign, process redesign, technology update, or product performance improvement, to make a product or process better. A common EC process undergoes four basic sub-processes: Proposal, approval, plan and implementation, and documentation [140].

Change is the only constant in life. Every aspect of life is bound to change within the boundaries of time. This also applies to our topic. It is important to convey many engineering improvements to a wide range of stakeholders. The system is also labor intensive, paper laden, and vulnerable to error. The most common framework and theory for managing EC today is the PDM system and CM theory. During the utilization of a PDM system, each engineering change request (ECR) requires a planned effectivity to be filled throughout the analysis and evaluation phases of an engineering change. To define all the necessary actions, the liability and the timing from the comprehensive design phase to the production phase in the life cycle of the product, a change effectiveness decision may be required [148].

EC refers to the situations in which an approved engineering design is not able to be manufactured for various reasons, one of them being the lack of necessary materials, but the manufacturing of an equivalent design is possible at the same time [149]. EC is a change to the current accepted configuration documentation of a configuration item (CI) at any stage in the life cycle of the item, according to CM principles.

The literature offers various terms and definitions for EC. Other slightly differing terms used for EC are: Engineering design change, product change, design change [151].

Her are some of the proposed definitions for EC:

EC is a modification to a component of a product, after that product has entered production [155].

ECs are the changes and modifications in forms, fits, materials, dimensions, functions,etc. of a product or a component [156].

ECOs are changes to parts, drawings or software that have already been released [157].

ECs are changes and/or modification in fits, functions, materials, dimensions, etc. of a product and constituent components after the design is released [158].

EC is an alteration made to parts, drawings or software that have already been released during the product design process. The change can be of any size or type; the change can involve any number of people and take any length of time [159].

As suggested by [160] and [161], the distinction between these meanings can be visually illustrated by mapping their coverage against a product life cycle. (see Figure 2)

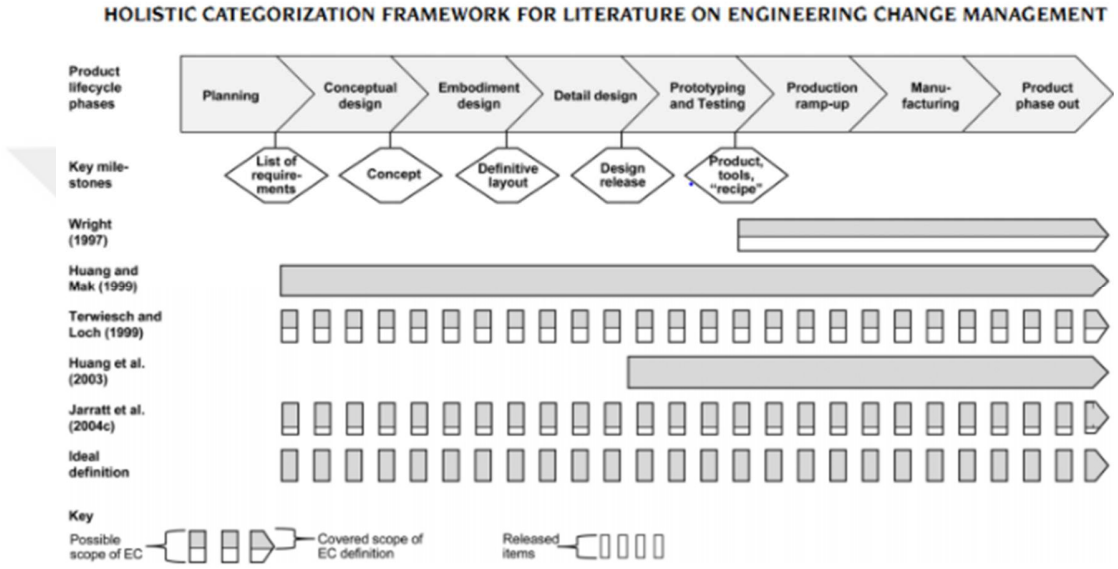

Figure 2 : Mapping of EC Definition to the Product Lifecycle [161]

4.4.1. Ecm Framework

A new categorization system has been created in order to provide a broad overview of the state of ECM research and to enable a more consistent positioning of the related publications (see Fig. 5). The structure's key blocks are,

(A) Prechange stage, is subdivided into the categories

(A.1) People-oriented,

(A.2) Process-oriented,

(A.3) Product-oriented research.

In order to build understanding about ECs and to provide people with experience and expertise of how to manage them, people-oriented research deals with the preparation

and growth of designers and other staff across the whole process chain. Product-oriented research focuses specifically on the architecture of products and covers topics such as variation design, changeability design, axiomatic design, resilient design, set-based design, architecture of processes, management of specifications and scalable product platforms.

(B) Processes, methods, processes, strategic guidelines, and organisations to manage ECs as they arise are included in the change stage. This block is categorized into

(B.1) Management problems,

(B.2) Strategic guidance,

(B.3) ECM processes,

(B.4) Procedures & IT Instruments,

(B.5) ECM process groups.

(C) The level of post-change is subdivided into groups.

(C.1) Delays,

(C.2) Cost,

(C.3) Quality,

(C.4) Phase of pre-production,

(C.5) Phase of manufacture & post-production,

(C.6) General sources & impacts.

(D) General studies & surveys. They are defined below (see figure 3)[162].

In this description, the adjective technical is applied in a wider sense to distinguish ECs from changes to non-technical artifacts, such as e.g. laws), artistic (e.g. painting), or architectural (e.g. building construction). Artifact works as an umbrella term that may refer to a single part, component, an assembly, a system, or a whole product. The software and controller units may be components and are included in this description of such technological objects. Changes in the manufacturing process or tools, can lead to those when they require changes to released product properties [161]. This concept is in accordance with the five modes of gradual design change which differentiate between "explicit" and "implicit" characteristics. While explicit attributes refer to the characteristics that are required on the drawings, technical documents, etc., implicit attributes emerge from them. The former defined the product's structure and the latter

defines its behavior and function. Five modes of gradual change in design leading to the creation of designs over time are specified on the basis of a context consisting of these attributes, design space, and product requirements [163]. These modes can be mapped to the product domains structure, behavior, and function as shown in Table I.

Table 1: Mapping of McMahon's Modes of Design Change to the Product Domains [162]

McMahon's modes of design change	Product domain
1. Parameter space exploration. Variation of explicit attributes within the limits imposed by feasible explicit attribute set.	Structure
2. Improved understanding of explicit-implicit attribute relationships. Exploiting an improved understanding of the relationships relating implicit to explicit values through improved analytical techniques, modelling or mathematical methods, experiments etc.	Structure-behaviour relation (physical laws)
3. Change in product design specification. **3i.** Change in the specified values of implicit or explicit attributes or external factors that the design must meet. **3ii.** Change in utility function for the design, e.g. emphasis in automotive design from performance to economy. **3iii.** Extension of the set of functional requirements that the design has to meet.	 Behaviour Function Function
4. Modifying the feasible design space. Development of the design due to change of explicit attribute space as a result of innovation e.g. by manufacturing process improvement such as reduction of minimum wall thickness for a casting.	Structure
5. Changing the design principle. Adoption of an alternative design principle with different design space.	Behaviour-function-relation (design principles)

ECM is the management, execution, and organization of EC's [164]. Furthermore, it covers the life cycle of the product, from the choice of a design to the wind-down of development and help. The main goals of ECM involve the avoidance or reduction of the amount of ECRs before they occur, selecting their implementation effectively when they occur, implementation of the required ECs efficiently, and learning from the already implemented ECs. These five objects termed as Less, Earlier, More Effective, More Efficient, and Better by [165].

ECM can be considered to be the foundation of greater CM [164]. The latter aims to develop and maintain the continuity of the performance, functional and physical characteristics of a product with its specifications, design and operational information throughout its lifetime [ANSI/EIA-649,1998]. CM is an essential discipline in the systems engineering area [166-167].

The classification scheme suggested here synthesizes the essence of both the EC and the way pre-change goods are managed, so the divisions of taxonomy are as follows:

Categorization of a product as ‘scrap’ means it has either severe technical errors or user safety problems. As a result, EC is needed as soon as possible. It is appropriate to scrap the work in progress (WIP) of the pre-change product and all the not yet assembled components which can not be included in any other product.

Categorization of a product as ‘rework’, means that the product requires some enhancements, either manual or not, in order to revise WIP characteristics.. Similar to the scrap situation, several functional problems also occur. However, they are not so serious; They can therefore be overcome quickly. As a consequence, the rework operation suggests any changes without affecting all finished products and components in the pre-change product WIP.

Classification of a product as ‘use-as-is’ means that it has no functional or consumer protection concerns and EC has the following purposes: Improving product performances, incorporating a new technology, making the production process easier, reducing production costs, improving the quality of component parts, standardizing BOM, through the use of interchangeable parts that can be used in BOMs of various finished goods. In addition, EC enables to produce and sell (in other words ‘use-as-is’) the pre-change product during the improvement of the product design, the pre-change product since it functions well [142]. When evaluating a transition, the following details relating to manufacturing and development must be considered.

Inventory status of the new and old item: The information regarding the amount of old items in the inventory should be managed. Whether they are to be scrapped, be used on other products or reworked should be decided by considering the cost of rework or scrap. The status of the new item should be traced to manage inventory.

Production status of the new and old item: The number of old items that are in work-in-process should be tracked. Whether or not they can be reworked to the new arrangement regarding their current stage of completion, completed and used up before the change is effective, or be scrapped should be decided. The information regarding the production processes of the new items, their lead time, and cost for production is

significant. Furthermore, additional lead time for building tooling, fixtures, and test equipment should be considered.

Procurement status of the new and old item:The procurement status of the items should be acknowledged. The flexibility regarding the cancellations and reworks should be managed with respect to their costs. It is also important to manage the lead time for procuring the new item and decide whether new suppliers are required.

The impact on the distributors, dealers, customers and field service organizations: Required notifications and duration of notification processes should be considered. Whether the documentation, manuals, and catalogs need to be updated and the implications on spare parts requirements should be analyzed.

Whether the changes are important enough to require testing and the kind of testing that is needed to be performed should be considered. Required regulatory approvals and the need for recertification of the product should be analyzed.

From PDM perspective, baseline status of as-design and as-built configuration. The amount of as-built CI and as-design CI involved should be considered. Typical revision activities include assigning control numbers, identifying items and documents impacted, conducting technical assessments, calculating costs, making business decisions, executing planning, reviewing baselines, validating and publishing documents, maintaining records, etc.

Change process status: Because there are no changes that are identical, they all go through different combinations of the same work centers: The process of engineering change is more like a workshop environment. One of the aims of an engineering change process may be workload balance as one work center can be filled with work while another has very little to do. Staff with the highest priority travel very rapidly through the entire phase of transition, while others are at a standstill [150].

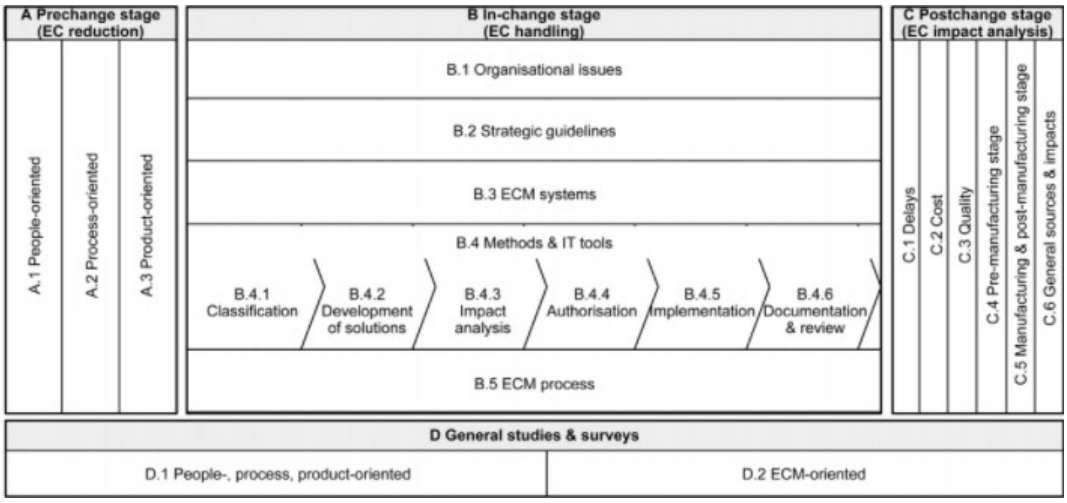

Figure 3 : Holistic ECM Research Categorization Framework [162]

4.4.2 CMII-Based Engineering Change Management Framework

The CM Institute recognized the significance of a structured system for the management of engineering change and created the Configuration Management II (CMII) model[173-174]. To build a structured engineering change management system, the CMII model can be used as a conceptual guideline. However this CMII-based system needs to further explore incorporating a Full-track or Fast-track mechanism from a realistic viewpoint to address challenges at various stages of product functionality or efficiency unique to the individual sector and its products. Critical mechanical deficiencies with safety criteria, for example, require a full-track process, whereas a fast-track process is needed for functional changes such as color shift.

The CM II model was developed from a related viewpoint by the Institute of CM [174]. This model includes systematic advice on the management of goods, facilities, and procedures by the management of their relevant knowledge, and expands the reach of CM to cover all information that could have an impact on protection, consistency, scheduling, prices, revenues or the business climate. There are dual cycles in the original CMII model (i.e., requirements and physical items). These two cycles involve eight work items and four key stages (described in the following) (i.e., plan, do, study, and act). All operations are requirements-driven in the CMII model i.e., requirements play the lead role and requirements must be fulfilled by physical objects. A quick and efficient process of change is required by the CMII model.

Three people join all operations in the process of engineering change control, such as the developer, the customer, and the Change Review Board. The creator, such as the product manager, is responsible for initiating requests for change and executing actual activities for change. Thus the operations in all processes will be joined by the maker. A machine consumer or client in possession of a device may be a user. Therefore should it affect the customer until the final service or product is complete, a user must assist in the analysis of a modification request. The Change Review Board is a committee consisting of representatives from all divisions of a particular organization, such as project managers. The Change Control Board's primary role is to review proposals for improvements and determine if they can be implemented [173-174].

The dual cycles in the original CMII model contain eight work items:

Schedule and Baseline,

Work Authorizations,

Perform Work,

Verify Conformance,

Change Requests,

Change Notices,

Upgrade Documents and Data,

Validate and Release.

First, based on the need to execute a change, the developer defines change-related challenges and sets up a comparable baseline and schedule plan. Second, in the Job Authorizing stage, the developer then integrates and submits these concerns to the change control board for review and acceptance of primary change issues. Third, the creator enters the perform work stage and completes the engineering change pilot test when issues are understood. Fourth, the creator evaluates experimental findings (before and after) after the pilot test and prepares a study in the verify conformance stage based on pilot-test results. Fifth, the creator creates a modification proposal according to the documentation in the change request stage and submits this request for approval to the change review board.

Users engaged in this project and debate during this analysis period. If the evaluation outcome is to condemn the engineering change, this change is likely to be terminated; otherwise, to execute a new pilot test, the work authorization, perform work,

and check conformance measures are added. The maker then sends to the change control board the change proposal. Sixth, after the proposal for change meets the review protocols, the creator sets up a note of change based on the requirements submitted and, seventh, documentation and report changes are done based on those specification.

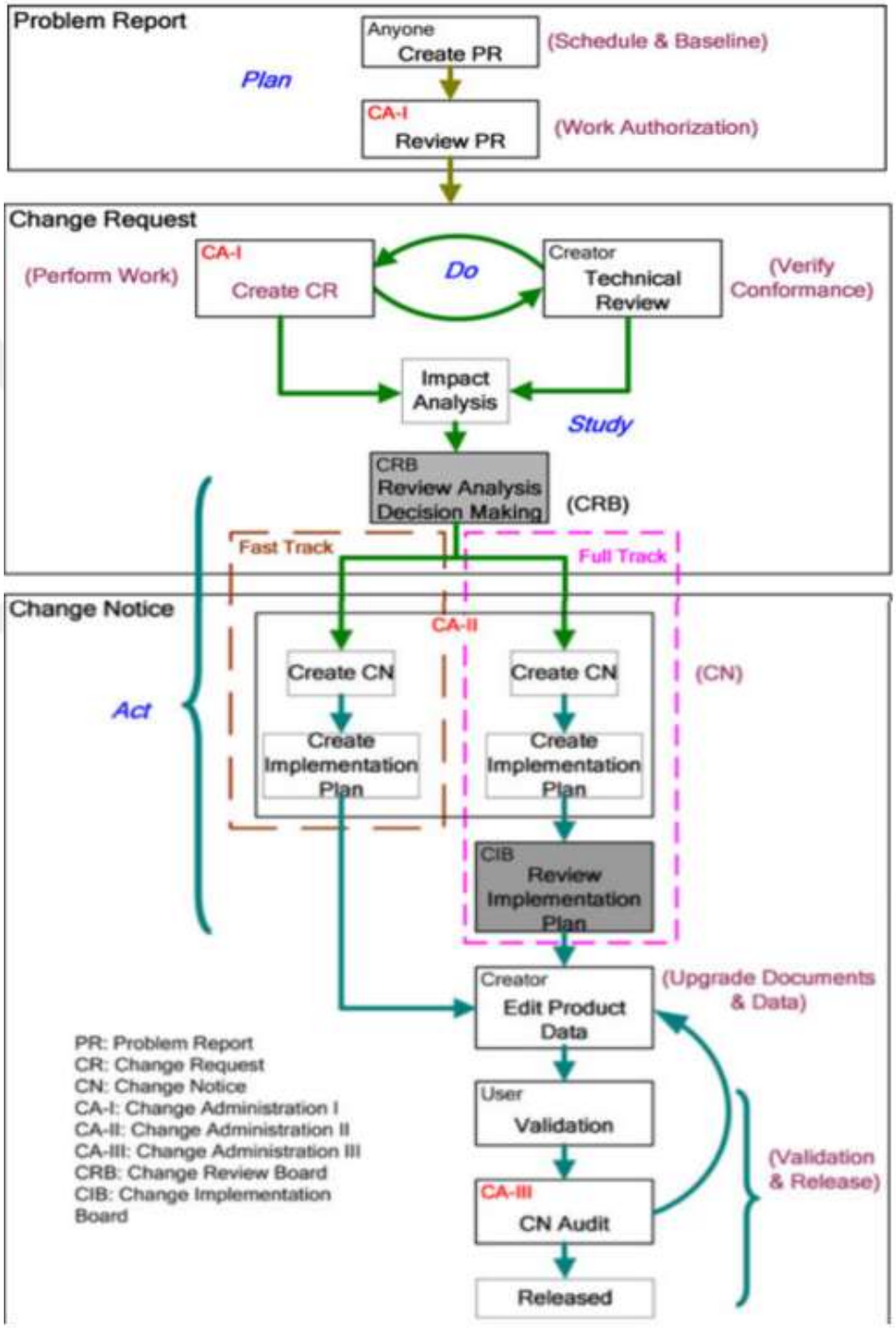

Figure 4 : CMII-Based Engineering Change Management Framework [176]

4.4.3. Proposed ECM Framework

The ECM process begins with the formation of an EC Committee that should oversee the whole life cycle of the EC. From the beginning of the process, it is important to integrate partners, upper management, and members from the rest of the departments. This will ensure support from senior management and satisfaction from customers.

4.4.3.1.A Five-Stage Model

The method, with the following steps is the proposed ECM framework:

Proposal stage, to ensure that the stakeholder, the company, and the consumer are pleased, the committee reviews the proposal. It is important to convey the principles, strategies and priorities of the project and to teach them directly across both stakeholders. At this point, the use of the expertise and understanding of experts from various departments and stakeholders comes in handy.

The acceptance stage uses the experience of the members of the committee to evaluate the advantages of the plan. Sometimes because of the lack of awareness of the future value of the initiative, ECs struggle to obtain the requisite support. Tools that can help clarify the meaning of the EC project should be part of a successful framework. Tools for system analysis, such as system dynamics and simulation of discrete-event processes, may be implemented using acceptable cost-benefit performance management methods. To measure the potential advantages of the initiative, holistic approaches, such as a balanced score-card, can be used. A holistic assessment should be the basis of the final decision to approve the plan.

The preparation stage is accompanied by the creation of a comprehensive action plan after the project has been approved. In order to fulfill stakeholder objectives, corporate priorities, as well as consumer expectations, all steps and benchmarks should be put in place to ensure the progress of the initiative. The drafting and finalization of the proposal should include all the stakeholders. It should be noted that at this point, it is necessary to include and involve staff on the ground who will be participating in the actual implementation of the EC. As addressed under the ECM essential success factors, the delivery strategy involves preparation for an enabling climate for the EC project's success.

The planning process is replicated iteratively until a satisfactory plan is developed which sets out the required conditions for the successful execution of the EC project.

The execution phase, with a well-defined framework and goals of the programme, a well-trained and dedicated team of experts, ensures an effective delivery of the project. Enough support from senior management ensures adequate funding and mission support. Furthermore, worker participation and participation protects against inertia and resistance to change. The total life cycle of the project to change engineering is ensured to be a success.

The documentation stage must be recorded for each EC project. There should be evidence of the experiences, observations and information acquired during the process. During the method, challenges, hurdles and enablers found should all be checked and reported for future usage.

During the first two steps, thorough review of the EC design is carried out to ensure that the EC project is compatible with the corporate needs and that it is either the correct approach to the issue identified or that it solves the identified opportunity before the EC project begins preparation. In either of the first two steps, the EC plan may be terminated if it does not pass the criteria for any of the two phases [141].

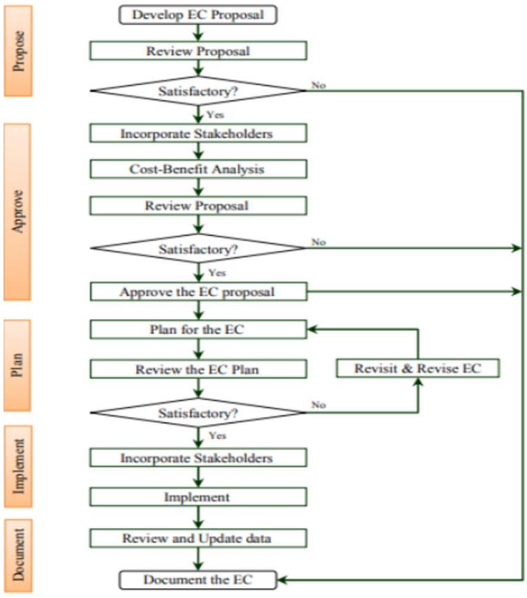

Figure 5 : Proposed ECM Framework [141]

4.4.3.2 Processes for EC

The mechanism is divided into two phases was suggested from by **Dale:**

- Approval process for ECs
- Method on approval [168].

4.4.3.3 A Five-Step Method Model

This model was suggested by Mallu, including the steps:

- Filtering of change proposal,
- Designing investigation of change,
- Design appraise,
- Authorize change,
- Execute change [169].

4.4.3.4 Three Steps of Engineering Change Management

Rivière proposed the below framework for the engineering change management process.

- Proposal from the EC
- Inquiry into EC
- EC implementation [170].

4.4.3.5 Four-Stage Model

Lee suggested a four-stage model for the structured ECs process, including the steps,

- Initiation of an ECR
- ECR Review
- Issuing instructions for ECOs to relevant parties, and tailed process steps for each level are stored and evaluated by ECOs for management purposes [171].

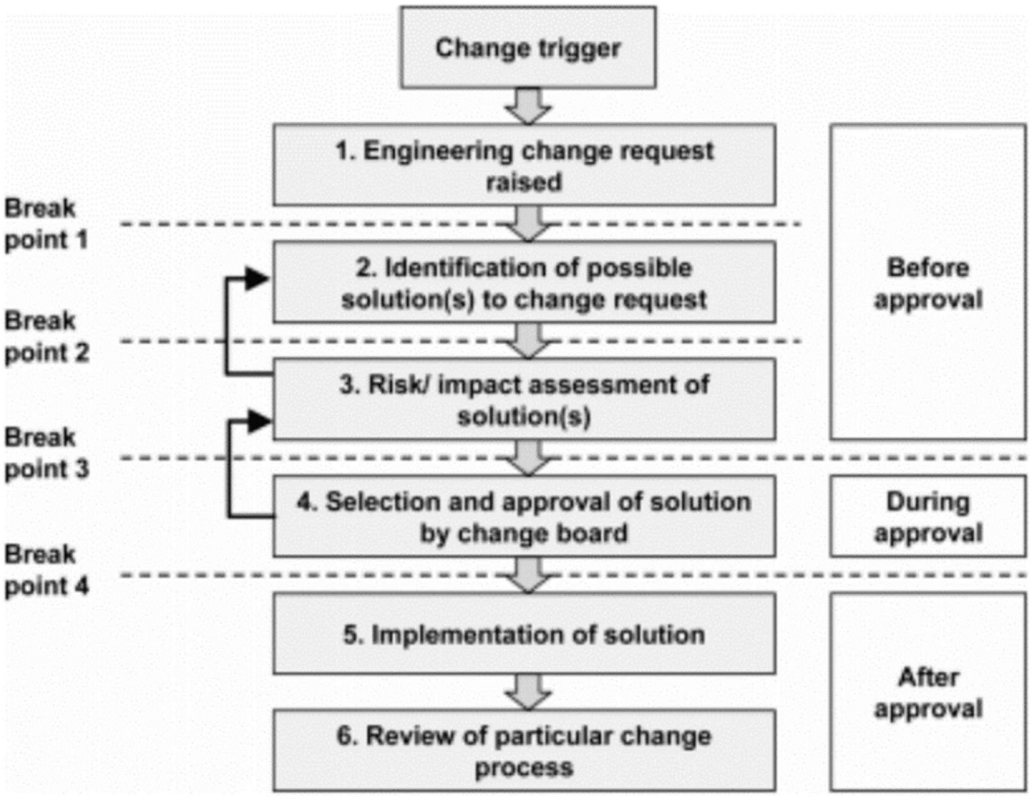

Figure 6 : Six-Step EC Process Source Adapted [172]

4.4.3.6 Systematic Three-Stage Process

The entire life cycle of ECs, from their initiation through their deployment to their analysis covers this generic process. As seen in Figure 6, it is structured into six stages and three phases [172].

4.4.3.7 Change Procedure and Execution Process

- Discovery and proposal of engineering problems,
- Execution project of engineering change,
- Engineering problem measurement and input, as is seen in Figure 7.

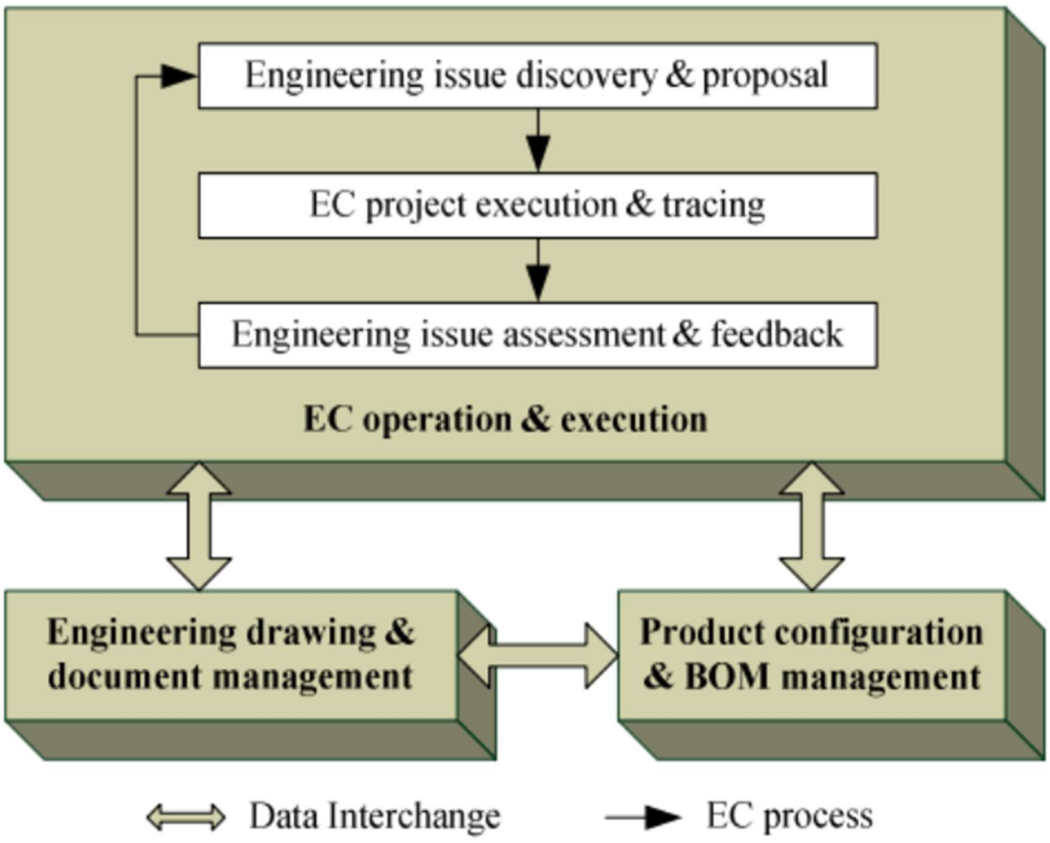

Figure 7 : Engineering Change Management Reference Model [147]

The need for an improvement is perceived and put in an ECM scheme by an initiator in the engineering issue exploration and proposal period. An engineering team member dealing with the design specification or a product department who has defined the issue in development may be the initiator. The effect of the change and the EC's preparation are already being built for implementation. The aim of this step is to gather as much information as possible at the early stage of the EC process. The details obtained in this stage relates to the aspect to be modified; the reason for the change; the technical drawing representing the change, etc. The roles are specified in a project during the execution and tracing stage and the EC is integrated into the production system. EC project execution is directed at incorporating ECs and reducing downtime and costs.Engineering issue assessment and feedback provides an assessment of the phase of technical change. There are three ways to assess the actual state of the practice of engineering change in an organization:

Total of ECs active;

Calendar time required for dealing with an EC;

The expense or time taken to process an engineering change (personal hours) [144]. This step also describes the information that was learned during the EC process. The information above will be stored as a document in the IS of engineering change management and can be used in subsequent EC processes.

The whole phase of engineering modification is followed by engineering drawings and documents. These documents have titles such as ECR and ECO. ECR is a form open to any employee that is used to identify a potential improvement or issue that could occur in a particular product. ECO is a document explaining the accepted engineering change to a product and is the authority or directive responsible for applying the change to and documenting the product [145].

Product configuration management is a discipline that uses technical and administrative guidelines and reporting to define and document the functional and physical characteristics of a configuration object, track changes to those characteristics, record and report documentation of changes and implementation status, and check compliance with specified requirements [146].

4.4.3.8.EC Operation and Execution Knowledge Management System Structure has five related modules,

- Engineering Problem Detection and Proposal Management,
- EC Project Execution and Tracing,
- Engineering Issue Evaluation and Input Management,
- Statistical Analysis and Monitoring,
- EC Management E-learning (see Figure 8.)
- The Module for Exploration of Technical Issues and Proposal Management is a forum for the compilation of engineering problems that provides a contact mechanism for a company's internal teams, vendors and consumers. Because any supply chain member may facilitate engineering reform, it is difficult to extract the completed engineering problem knowledge from only one study. Communication numbers are needed to explain the phenomenon, cause and impact

of an engineering challenge. Often the correspondence continues for several months for a certain problem.

To maximize communication performance, the Kanban method is used to store and scan communication reports and to better explain the various supply chain participants. The engineering problem evaluation and feedback management module is used to test Kanban's project proposal. The recommendation must be tested whether the technical suggestion is relevant to the engineering drawing or specification of the consumer, the development process, and the supply chain. In order to increase evaluation performance, the information acquired through the EC process should be retained in the future for case-based reasoning. The execution and tracing module of EC projects is split into five sub-modules:

Implementation of EC execution, the basic logic of which is that only an authorized and permitted engineering reform can be implemented for execution.

Temporary control of the EC, which is a streamlined method of the EC for a case of urgency.

Control of the assembled EC package used for a dynamic product with several BOM structures.

Part EC product management, which is set up under the EC assembled product management framework.

EC original data record implementation, which will eliminate mis operation and confusion in the communication process when there are numbers of dispute harmonization of business preparation and production planning, production planning and inventory of goods, quote adjustment of engineering and claim reimbursement, and etc.

The module for statistical analysis and monitoring allows engineering improvements in the product life cycle effectively. Managers can collect EC data quickly and monitor the EC process. The system's warning feature will warn managers and operators to finish the appropriate activity in a timely manner and to assess the situation and make good decisions when unexpected situations occur.

EC Management E-learning is used to train supply chain members to cope with the EC process [147].

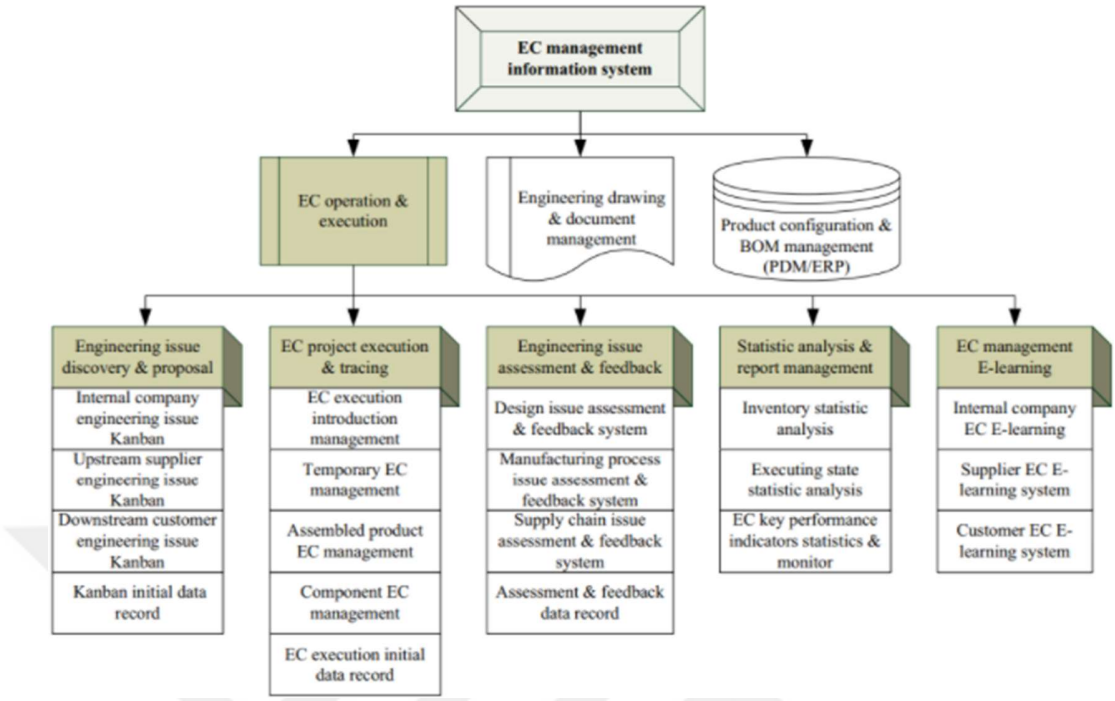

Figure 8 : The Framework of Engineering Change Management IS [147]

4.5. PLM PRACTISE & SIEMENS TEAMCENTER

Siemens Teamcenter X is a new PLM solution delivered as a service. It's a modern, highly scalable PLM suite that connects people and processes across functional disciplines. Teamcenter X brings the power of the cloud to all users, to help reduce time-to-market and connect distributed, cross-disciplinary teams. The easy to use interface, with predictive AI elements, helps users across the enterprise get up and running quickly and work smarter. It offers the convenience of choosing from preconfigured engineering and business solutions that deliver immediate value, with the flexibility to add more capabilities as business needs grow. It leverages a new and modern cloud platform with best practices built-in, and a business model in which Siemens has removed the burden of operating PLM for companies of all sizes. It can help customers realize PLM benefits quickly and streamline product development, and can be used by businesses of all shapes and sizes. The knowledge contained in Team center X can be integrated and extended across the entire enterprise. It is built on the Mendix™ software application platform, and the knowledge can be easily extended. It allows companies to deliver multi- domain products on time, with high quality, within budget, and exceeding customer expectations,

says Joe Bohman, Senior Vice President for Teamcenter. Siemens also announces Teamcenter Share, a new cloud-based, design-centric project collaboration service. Share enables product development stakeholders to synchronize desktop files to secure cloud storage. Siemens Digital Industries Software is driving the transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. The Xcelerator portfolio helps companies of all sizes create and leverage digital twins that provide new insights, opportunities and levels of automation to drive innovation, the company says. The company has its global headquarters in Nuremberg, Germany, and has around 76,000 employees internationally. In fiscal 2019, which ended on September 30, 2019, Siemens generated revenue of €86.8 billion and net income of €5.6 billion. At the end of September 2019, the company had around 385,000 workers worldwide. The analysts forecast the CAD market in North America to grow at a CAGR of 9.99 percent over the period 2012-2016. The key vendors dominating this market space are Autodesk Inc., Dassault Systems SA, PTC, and Siemens PLM Software Inc. The availability of open-source and pirated CAD solutions could pose a challenge to the growth of this market. Cloud computing technology is becoming increasingly popular among organizations because it offers huge data storage space, provides flexibility, and enables scalability. The pay-per-use model also reduces the overall cost of CAD software adoption. The CAD market is witnessing an emerging trend where vendors are increasingly developing cloud-based digital manufacturing software solutions to meet the huge demand from end-users [177].

The global digital manufacturing market for discrete industries achieved a moderate growth of 7.48% in 2017. It is expected to grow at a CAGR of 8.04%, owing to the rapid pace of technological advancements. Digital manufacturing is a subset of PLM and is an integrated approach to use computer technology for simulation, 3D visualization, and analytics. Companies such as Dassault Systems, Siemens PLM, Autodesk, and PTC dominate the market in discrete industries. Their strong position in the market is attributed to diverse product portfolios, robust distribution networks, and diverse application coverage. The study also provides information on key end users like automotive and transportation, aerospace and defence, heavy machinery, and hi-tech electronics and discusses opportunities for digital manufacturing in these industries [178].

PTC has been named a leader in the new research report "IDC Marketspace: Worldwide Retail Brand Product Innovation and PLM 2016 Vendor Assessment" PTC's retail solutions help retailers and brand owners simplify the complex challenges of bringing products to market. The IDC Market scape examined the capabilities and strategies of 12 key vendors in the retail brand product innovation and PLM applications market. "The bar has been reset for excellence in retail brand Product innovation and PLM platforms," says IDC Retail Insights vice president. "We are honored to have been selected as a leader," says Eric Symon, general manager, Retail Business Unit, PTC. The PTC solution integrates end-to-end product development and supply chain capabilities. It enables end users to plan, create, develop, source, cost, and follow finished goods through their lifecycle to achieve rapid time-to/value. The report goes on to say, "retail brands can now also leverage PTCs fairly recent portfolio addition ThingWorx, an award-winning platform for building and running applications for the Internet of Things. The retail solution provides a robust portfolio and IoT technologies to meet our customers' evolving needs and enable new ways of working in the digital world. PTC (NASDAQ: PTC) is a global provider of technology platforms and solutions that transform how companies create, operate, and service the "things" in the Internet of Things (IoT) PTC's next-generation Thing Worx technology platform gives developers the tools they need to capture, analyze, and capitalize on the vast amounts of data being generated by smart, connected products and systems. The company's field-proven solutions are deployed in more than 26,000 businesses worldwide to generate a product or service advantage. PTC, the PTC logo, Windchill, FlexPLM and Thingworx are trademarks or registered trademarks of PTC Inc [179].

Siemens PLM Software recognized as market position leader in the fastest-growing segment of the industry. For the seventh consecutive year, CIMdata rated Siemens PLM Software as the industry leader in Digital Manufacturing. The company has seven million licensed seats and more than 71,000 customers worldwide. The collaborative Product Definition Management (cPDm) business segment will achieve a five-year CAGR of 11.5 percent. The mainstream PLM market is expected to rise by more than ten percent at a 5-year CAGR of 10 percent by 2016, according to CIM data. To receive this honor for so many consecutive years is a testament to our team's unwavering

dedication, says Chuck Grindstaff, president and CEO, Siemens PLM Software. Siemens PLM Software is rated highly as a major player in the process PLM segments. The Discrete PLM market segment accounts for the strongest overall market growth. The company's NX software and Solid Edge software are ranked as leading solutions for the CAx segment. "To be evaluated by IDC Manufacturing Insights and come out as an industry leader is particularly gratifying," says Chuck Grindstaff, president and chief technology officer, Siemens PLM Software. "PLM market leaders command a firm grasp of today's evolving PLm market," says Sanjeev Pal, senior analyst, IDC manufacturing Insights. "We've seen market dynamics that support IDC Marketscape's findings and we feel we'll only continue to strengthen our leading position as we go forward," says Grindstaff. Siemens PLM software's strategy and capabilities held leading positions in each of the three market segments evaluated and showed positive momentum in the market, an uncommon result in IDC's Marketscape report. Siemens PLM Software is a business unit of the Siemens Industry Automation Division. The division has 6.7 million licensed seats and more than 69,500 customers worldwide. The portfolio ranges from standard products for the manufacturing and process industries to solutions for whole industrial sectors. With around 33,000 employees worldwide, the division achieved sales of €6.2 billion in fiscal year 2010 [180].

Teamcenter gives you the opportunity during the whole lifecycle of a product to define, authorize, sequence, and verify product changes (development to the product as part of the new version of it). CMII's best practices are the foundation of the corporate method of change management, change the engine, change approach, change execution, change integration. The Change Driver Process contains the details required to validate and replicate any identified issues or to record the detail of an upgrade request. Additional attributes record the potential severity of the problem and set the focus relative to other incident reports for resolving the problem. In Change Manager, a problem report is considered an incident report. The Change Driver Process contains the details required to validate and replicate any identified issues or to record the detail of an upgrade request. Additional attributes record the potential severity of the problem and set the focus relative to other incident reports for resolving the problem. In Change Manager, a problem report is considered an incident report. The change implementation mechanism requires the

permitted change approach to be realized, registered, and implemented. The consequences of the transition are stored by a change execution collector. It offers a comprehensive work schedule to discuss one or more possibilities for improvement. A change implementation collector is considered an engineering change notice (ECN) in Change Manager. During design construction, procurement, and construction to manufacturing the new product, the transition integration process provides the implementation of the updated product concept [176].

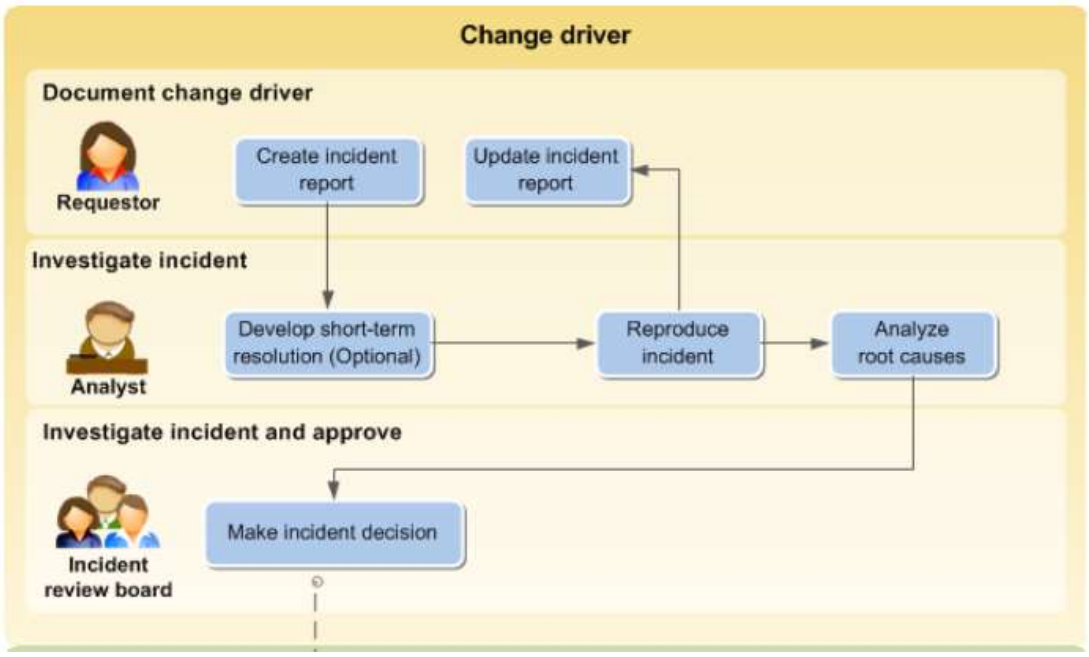

Figure 9 : Change Driver Process [176]

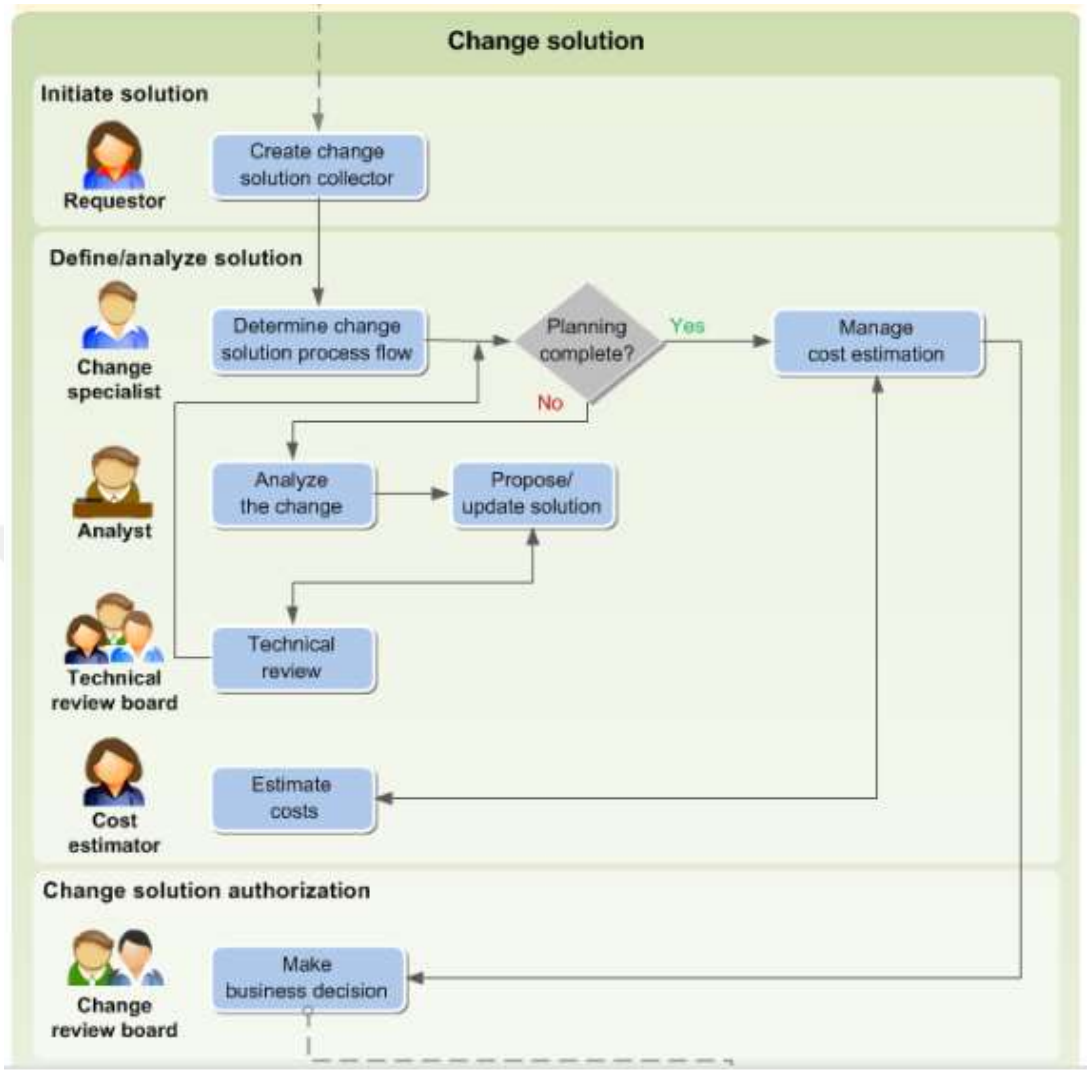

Figure 10 : Change Solution Process [176]

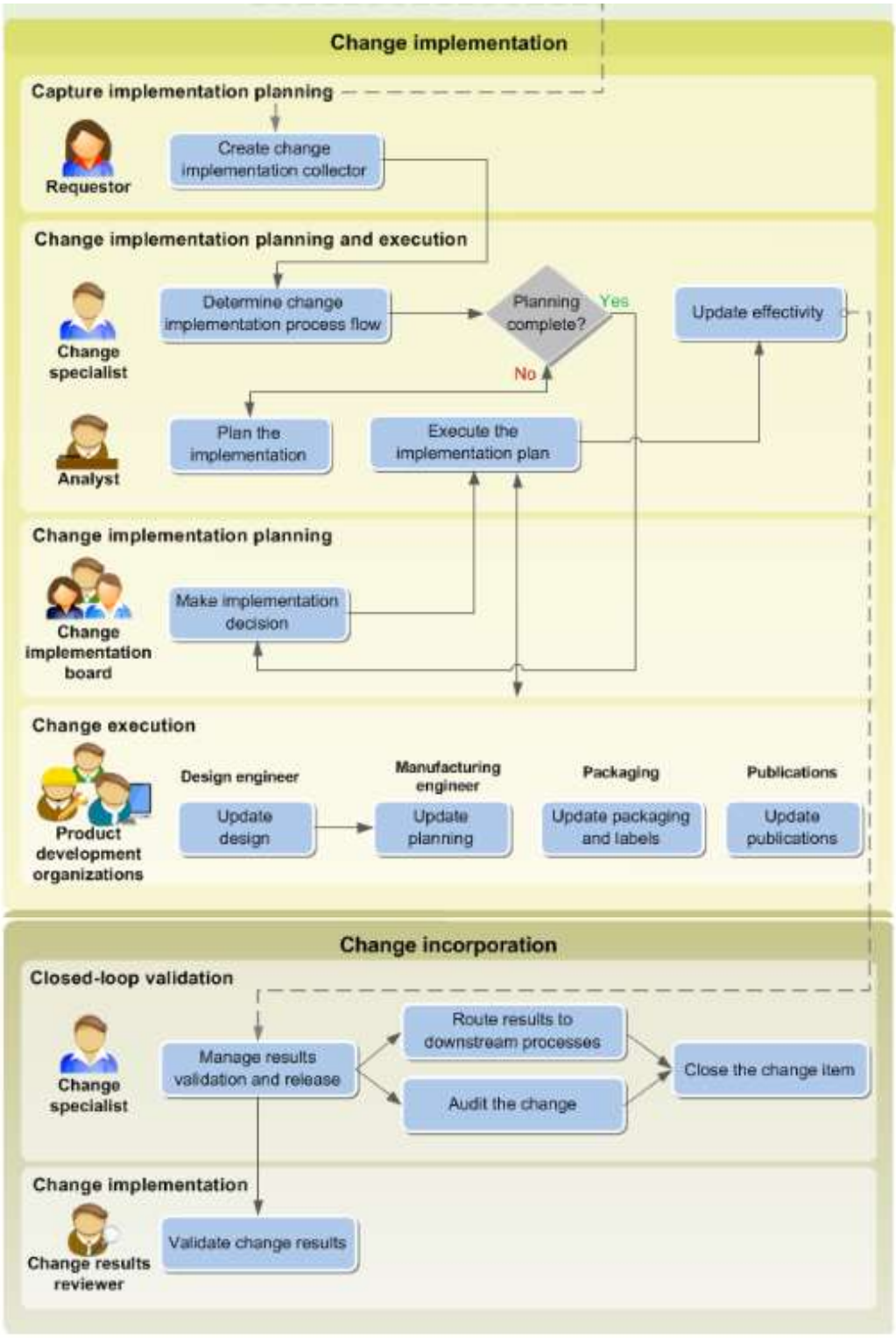

Figure 11 : Change Implementation and Incorporation Process [176]

CHAPTER V
PROPOSED ADVANCED CM-II BASED ENGINEERING CHANGE MANAGEMENT FRAMEWORK

Engineering change management is crucial for a company to stay relevant and meet customer requirements. Customer demands tend to change more frequently with the advance of the internet and globalized markets. In order to cope with the changes in demands and preferences of customers, companies come up with different products and variations of products to offer a wider range of options. A well-managed engineering change process will enable companies to create new market opportunities, meet customer demands, and adjust to the various market requirements. CMII Change Management is the process of initiation, designing, reviewing, and implementation of the required changes of the products using CMII best practices. This study elaborates on a Change Management Framework from a CMII approach.

5.1 PROCESS-CONTAINERS-ROLES

There are 3 main processes in the proposed ECM whose theoretic approach is CM II engineering management.

1.Change Trigger

2.Change Solution

3.Change Implementation

Each process has a business flow diagram which is encapsulated with containers are,

- Problem Report,
- Customer Requirement,
- Change Analysis,

- Supplier Business Analysis,
- Plan Change Implement,
- Release Change,
- Supplier Change Implementation Process,
- Quality Control.

In this framework work roles are shared ,

- Requestor,
- Analyst,
- Incident Review Board,
- Change Specialist,
- Technical Review Board,
- Customer,
- Change Review Board,
- Quality Administrator,
- Change Implementation Board.

5.2 PROBLEM REPORT CONTAINER

The requestor can create incident reports that relate to any event, incident, problem, and issue concerning the product life cycle management. The role involves any stakeholder who has the right on product lifecycle to improve it constantly. Expectations from them include risk management and taking other mishaps into account for the sake of PLM. There can be many forms of incident, examples include Injury Incident Report, First Aid Incident Report, Workplace Violence Incident Report, Information Security Incident Report, etc.

The role of the Analyst can be assigned not only to the designer but also to the manufacturing engineer. Analysts examine the incident and adopt a different perspective than that of the business analyst. The Analyst also updates the incident reports if needed. Furthermore, they conduct root cause analysis.

Incident Review Board is composed of three roles. These roles may be designers, manufacturing engineers, and change specialties. Mostly, a change specialist is an

expected role since the process shouldn't be consuming much effort at this stage. There can be five different dispositions on IR:

IR CLOSED": Since IR has no impact on PLM or because it is already implemented, the decision would be: "IR CLOSED".

IR can evolve to the "ECONOMIC CHANGE MANAGEMENT" framework: IR has a considerable impact on the economic changes on product-related attributes like income levels of the consumer products, consumer tastes, or fluctuations of prices regarding a related product [181].

IR can evolve to the "ORGANIZATIONAL CHANGE MANAGEMENT": In such a situation, the board can give a disposition related organization like the implementation of new technology/IT infrastructure [182].

IR can be updated as an "ECR": Once IR matures as an engineer; it evolves to engineering change requests.

Update IR: It gives information regarding whether IR needs to be updated or it is mature enough to continue.

5.3 CUSTOMER REQUIREMENT CONTAINER

Requestor raises incident report,

Requestor reproduces incident report if incidence review board say so,

Change specialist closes incident if the board has made a decision.

The customer raises a request as an incident to serve the problem report process. The IR review board can provide feedback to the customer for the status of the incident. If the situation does not need disposition, the customer closes IR. In this situation, IR needs to be updated with customer updates. The content of the process' flows is contained in the incident report.

5.4 CHANGE ANALYSIS CONTAINER

There are two change boards in the CMII change process:

Change Review Board (CRB)

The ECR is evaluated by a cross-functional department that is composed of representatives from various organization divisions. This cross-functional department

makes a business decision as to whether to continue with implementation scheduling or not.

Change Implementation Board (CIB),

A cross-functional team with representatives from various divisions of the organization reviews the ECN's implementation plan and determines whether or not the plan is complete and ready for action.

Technical review board makes a decision on ECR, which are “Closed” or “Updated”.

Change Specialist, determines change process flow.

Sending ECR requests to the suppliers.

Making “Fast Track” decisions: Any change that can easily be operated as an arrangement between the data author and the user without bureaucratic delay should be managed by the quick track change division. Fast track changes bypass the CRB and are submitted directly to the Analyst and Change Specialist for implementation. For business decisions, full track changes are sent to the CRB.

Analyst, analyzing the change and proposing updates (if needed) and solutions.

Change Review Board has a decision regarding the dispositions that are impact cost, person-hour, lead time, and efficiency on ECR, which are:

Yes, ECR is available to evolve ECN.

No, it is not ready to evolve to ECN, then it goes to board again to be updated.

5.5 SUPPLIER BUSINESS ANALYSIS CONTAINER

Change Specialist, receives ECRs and then determines the change process flow.

Change Review Board gives dispositions regarding the impact cost, person-hour, lead time, and effectivity. Then the board makes the final decisions, which are: Feedback for change, ECR approved and ECR rejected.

5.6 PLAN CHANGE IMPLEMENT CONTAINER

Analyst and Change Specialist create “Engineering Change Notice”. At the same time, they inform suppliers to implement this change to their information system.

Change specialist determines the change implementation process flow.

Change Implementation Board reviews the implementation plan and then, the product data is edited and released.

5.7 SUPPLIER CHANGE IMPLEMENTATION PROCESS CONTAINER

Change Specialist investigates the needed change,

Change Implementation Board, reviews the implementation plan. When suppliers accept the change, after getting the release data, the change is implemented.

5.8 QUALITY CONTROL CONTAINER

Quality Control Admin ensures physical implementation of the release change on the product and audits the change with their related technical skills and tools.

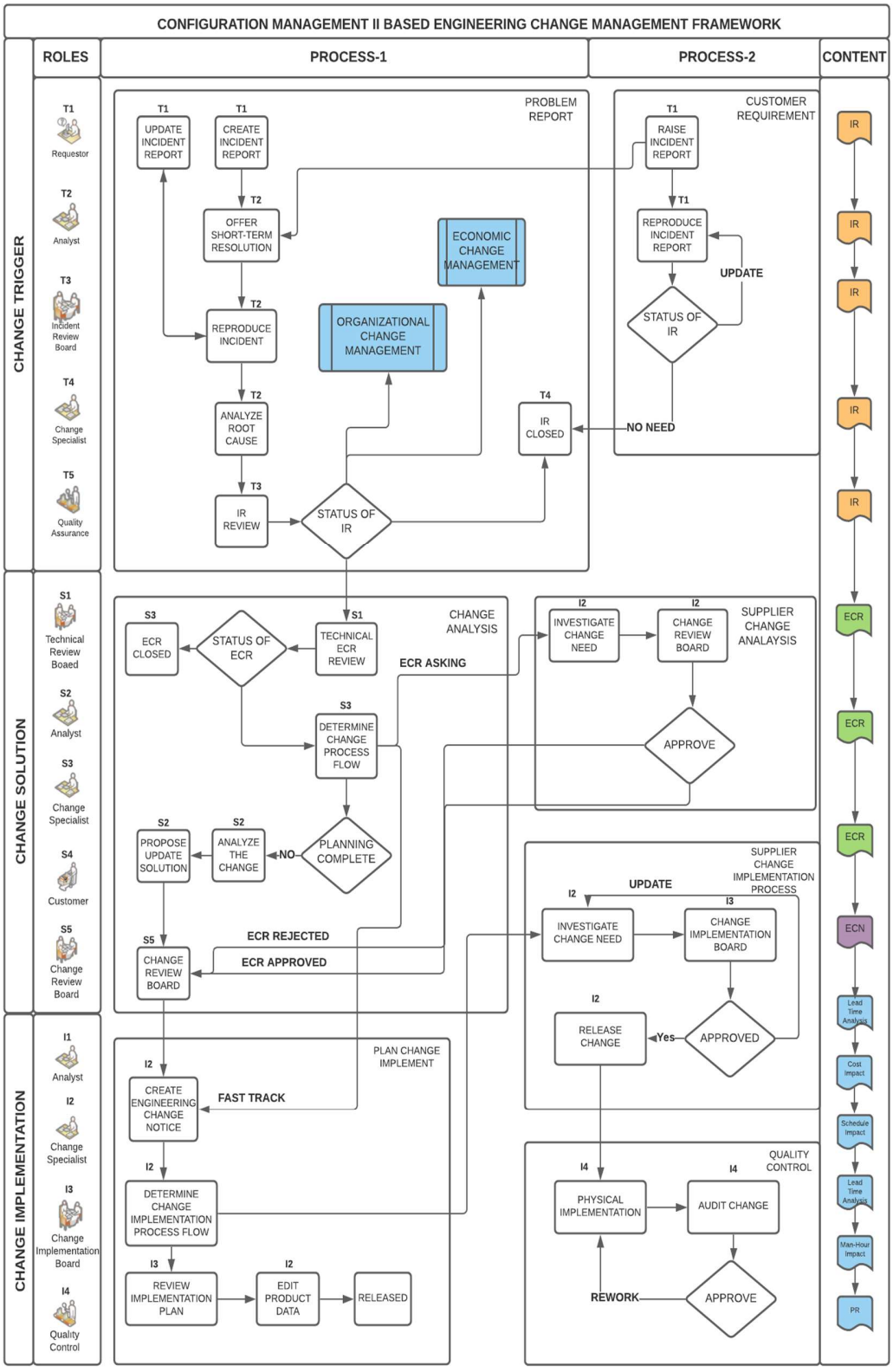

Figure 12 : CM II Based Proposed ECM by Author

CHAPTER VI
CONCLUSION

The Discrete Manufacturing method has been increasing its popularity among companies, especially when a new product is presented to the market or when cooperation is made in the production of an existing product. Product data integrity is of the utmost importance in such a context. Delivery of the product with the right configuration determined by the customer is crucial for product accuracy. Product data undergoes certain changes throughout the Product Lifecycle. PLM manages the lifecycle of the product and analyzes the product data. When a change occurs in the product data, the PLM system needs to be able to accord with that change, in order to manage the data. Determining the PLM CM method is a research problem both in the academy and in the industry.

Proposed ECM framework's method and theory stand respectively System Engineering and Configuration Management II. Not only the academy but also the industry has addressed solutions to the problem area in their studies.

Academy mostly focuses on the theoretical side of CM, which are Economical Change Management (ECM), Organizational Change Management (OCM), and Engineering Change Management (ECM). The industry has practical solutions for ECM like Siemens Teamcenter PLM. However, the industry needs more solutions that rely on theoretical studies. In this study, ECM and OCM are added as sub-processes since there may be alternative information unfolding after its review by the board. The report on the "incident review board" with the view that "incident reports" may affect the economy, or the organization can trigger the economic and organizational change management.

Configuration Management II theory enables the evaluation of product change not only through a design-centric approach but also through system and service-related perspective throughout its lifecycle. Since CM-II theory creates new processes for product

change management through its life cycle, PLM systems extend their work scope and increase their share in ERP systems.

The proposed framework can be tested in the industry in order to support the findings. When the framework was modeled, the modeling language-technique was determined as a unified modeling language-activity diagram (business flow diagram).

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