# AN OBSOLESCENCE MANAGEMENT FRAMEWORK FOR A DEFENSE INDUSTRY COMPANY

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF SOCIAL SCIENCES OF MIDDLE EAST TECHNICAL UNIVERSITY

BY

NİLÜFER SAYGIN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR

THE DEGREE OF MASTER OF SCIENCE

IN

THE DEPARTMENT OF BUSINESS ADMINISTRATION

JANUARY 2020

Approval of the Graduate School of Social Sciences

__________________________

Prof. Dr. Yaşar KONDAKÇI
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Business Administration.

__________________________

Prof. Dr. Z. Nuray GÜNER
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Business Administration.

__________________________

Assoc. Prof. Dr. Zeynep ONAY
Supervisor

**Examining Committee Members**

| | | |
|---|---|---|
| Prof. Dr. Nazli Wasti Pamuksuz | (METU, BA) | __________ |
| Assoc. Prof. Dr. Zeynep Onay | (METU, BA) | __________ |
| Assist. Prof. Dr. Melek Akın Ateş | (Sabancı Uni, SBS) | __________ |

**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

**Name, Last name:** Nilüfer SAYGIN

**Signature :**

# ABSTRACT

AN OBSOLESCENCE MANAGEMENT FRAMEWORK FOR A DEFENSE INDUSTRY COMPANY

Saygın, Nilüfer

MBA, Department of Business Administration
Supervisor: Assoc. Prof. Dr. Zeynep Onay

January 2020, 155 pages

This thesis presents an analysis of the processes related to the obsolescence management of electronic components in a large scale defense industry company. These proceses are: Project Management, Research and Development, Manufacturing and Services, and Supply Chain Management. The current obsolescence problems, and the company's reactive approach to resolving these are described. A new obsolescence management framework is proposed in order to mitigate and resolve obsolescence problems in electronic components. The framework targets the reduction of the negative impacts of obsolescence throughout the lifecycle of products, as well as the elimination of the communication and integration deficiencies in existing processes. It recommends the extension of the scope of Product Lifecycle Management in the company, the establishment of a companywide Preferred Parts List and standardization of existing electronic component libraries, the introduction of Complex Event Processing to manage obsolescence, and the incorporation of a new obsolescence management process within a "shell structure" that integrates all obsolescence related processes.

**Keywords:** Obsolescence, Obsolescence Management, Electronic Components, DMSMS, Defense Industry

# ÖZ


BİR SAVUNMA SANAYİ ŞİRKETİ İÇİN TEMİNSİZLİK YÖNETİMİ MODELİ

Saygın, Nilüfer

Yüksek Lisans, İşletme Bölümü
Tez Danışmanı: Doç. Dr. Zeynep ONAY

Ocak 2020, 155 sayfa

Bu tez, büyük ölçekli bir savunma sanayi şirketinde, elektronik malzemelerin teminsizlik yönetimi ile ilgili süreçlerinin analizini sunmaktadır. Bu süreçler şunlardır: Proje Yönetimi, Araştırma ve Geliştirme, Üretim ve Hizmetler ve Tedarik Zinciri Yönetimi. Mevcut teminsizlik problemleri ve şirketin bunları çözmek için reaktif yaklaşımı açıklanmaktadır. Elektronik malzemelerde teminsizlik sorunlarını azaltmak ve çözmek için yeni bir teminsizlik yönetim modeli şirket için önerilmiştir. Model, ürünlerin yaşam döngüsü boyunca, teminsizlik problemlerinin olumsuz etkilerinin azaltılmasını ve dahası mevcut süreçlerde iletişim ve entegrasyon eksikliklerinin giderilmesini hedeflemektedir. Bu model; "Ürün Yaşam Döngüsü Yönetimi" kapsamının genişletilmesini, şirket genelinde "Tercih Edilen Parça Listesinin oluşturulmasını" ve mevcut elektronik malzeme kütüphanelerinin standartlaştırılmasını, teminsizlik yönetimi için "Karmaşık Olay İşleme"nin başlatılmasını ve yeni bir teminsizlik yönetimi sürecinin şirketin teminsizlikle ilgili tüm süreçlerini birleştiren bir "kabuk yapısı" içinde kurulmasını önerir.

**Anahtar Kelimeler:** Teminsiz, Teminsizlik Yönetimi, Elektronik Malzemeler, AÜKMK, Savunma Sanayi

*This thesis is cordially dedicated to the Saygın family and Mustafa Kemal Atatürk.*

## ACKNOWLEDGMENTS

The prime acknowledgement, my warmest and deepest gratitude belongs unquestionably to my supervisor Assoc. Prof. Dr. Zeynep Onay for her extraordinary and phenomenal support as well as her unbroken faith and confidence in me from the origin to the completion of this thesis. No language would suffice in capability to define my recognition and sense of appreciation of her guidance and mentorship in this regard. This thesis would never come to life without her excellent consultance and supervision, experience and brilliance in the defense industry not to mention the field of expertise, illuminating my path and widening my vision that there are always new perspectives and angles to look from.

I would also like to thank Assoc. Prof. Dr. Seza Danışoğlu for her invaluable support of inspirational nature, for acting as a pathfinder throughout the MBA, and helping me achieve a better quality of research.

I am further grateful for the continual support, enduring patience, and foresighted guidance that I was gifted by my esteemed team leader Erdem Kanat. His splendid knowledge and expertise in the defense industry has been enlightening for me throughout the periods of research and writing. With his versatile approaches and multi-faceted perspectives, adept style of figuring out the best solutions even for the worst problems, he indeed paves the way for future research and achievements to attain. Far beyond a team leader, always guiding me like the Polaris even during the darkest of times, he never hesitated to lend support and advice like a kin in not only my professional but also social life.

I cannot thank enough my distinguished manager Mr. İsmail Özsaraç, who is also a pioneer of Obsolescence Management in the Republic of Turkey, for his inestimable support and encouragement on this work, which I cherish and deeply appreciate. Providing me with his extensive professional vision and far-reaching insights, he sheds light upon the path towards future research and the development of the subject matter in the Republic of Turkey.

Over and above, I am much obliged and thankful to Mr. Mustafa Barış Düzgün who is a pioneer of Obsolescence Management in the Republic of Turkey and who introduced me to the subject matter. His comments and critique on this work have been rather enlightening, and I genuinely appreciate his endless support and motivation, driving me to adopt a wide angle of vision at things.

Special thanks must surely go to Miss Özlem Özbay, who is also a pioneer of OM in the whole country, for being a guiding beacon to me and not refraining from supporting this work.

And I want to express my heartfelt thanks and earnest gratitude to my deserving friends from the academic years of MBA 2015 and 2016. Their friendship and support will always be appreciated and remembered. Additionally, my special thanks go to Merve Öztürk, Önder Aral Özkan, Selam Yiğit Özkan, Selin Taftaf, Görkem Gün, Buğra Ayvazoğlu, and Fikri Uğur Emek. Their valuable and supportive comments and suggestions have exceptionally been helpful.

I also want to express how thankful I am to my dearest friends, Ayşe Nur Dok, Nur Tuğana Akbayrak, Ömer Bağcıgil, and others. Their motivation and support through this process will not be forgotten. They are truly beyond brother and sisters to me.

Last but not the least, I would like to thank my beloved Saygın family who made it possible for me to attain what I have achieved in life, for their support, and for never giving up on me. They have always been by my side through the ups and downs. On all accounts, they have perpetually inspirited me to learn and improve as true advocates of progression and education. Without their love and guidance, I would not be the person who I am right now. Moreover, I should thank the universe as I consider myself very lucky to be among the progeny of this family, and a sibling to Gökhan Saygın.

Finally, I hereby dedicate this study to Mustafa Kemal Atatürk. In loving memory of his, I will always acknowledge and be grateful for everything he and his fellows achieved and sacrificed for this noble country and for its proud citizens.

May he rest in peace, among the stars, across the heavens.

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ARINC | Aeronautical Radio, Incorporated |
| BOM | Bill of Materials |
| CADMID | Concept Assessment Development Manufacturing In-service Disposal |
| CCA | Circuit Card Assembly |
| CEP | Complex Event Processing |
| COTS | Commercial – off-the-shelf |
| CPPL | The Company’s Preferred Part List |
| CS | Consignment Stock |
| CfA | Contracting for Availability |
| DRP | Design Refresh Planning |
| DE&S | Defense Equipment & Support |
| DoD | Department of Defense |
| DMEA | Defense Microelectronic Activity |
| EOL | End of Life |
| ECDTL | Electronic Card Design Tool Libraries |
| FPGA | Field Programmable Gate Array |
| FFF | Form Fit Function |
| LTB | Life-time Buy |
| LRU | Line Replaceable Unit |
| LOT | Life of Type |
| RML | Reactive Management Level |
| PML | Proactive Management Level |
| SML | Strategic Management Level |
| MoD | Ministry of Defense |
| MPN | Manufacturer Part Number |
| NRND | Not Recommended for New Designs |
| NPV | Net Present Value |

| | |
|---|---|
| MRP | Material Requirements Planning |
| OCM | Original Component Manufacturer |
| OMP | Obsolescence Management Plan |
| OM | Obsolescence Management |
| OMT | Obsolescence Management Team |
| PPAP | Production Part Approval Process |
| PCN | Product Change Notification |
| PCB | Printed Circuit Board |
| PDN | Product Discontinuance Notification |
| PLM | Project Lifecycle Management |
| POMP | Project Obsolescence Management Plan |
| POMP DP | Project Obsolescence Management Plan Document Package |
| PPL | Preferred Part List |
| R&D | Research and Development |
| SCH | Schematic |
| UK | United Kingdom |
| US | United States |
| WLC | Whole Life Cost |
| WLCC | Whole Life Cycle Costs |

# CHAPTER 1

# OBSOLESCENCE MANAGEMENT OF ELECTRONIC COMPONENTS IN THE DEFENSE INDUSTRY

## 1.1 Introduction to Obsolescence Management of Electronic Components

Obsolescence is the unavailability of components from their original manufacturers due to the end of their product lifecycles (Sandborn, 2012). Obsolescence of electronic components, when they cannot be produced by original component manufacturers, or cannot be found in the electronic components market, create obsolescence management (OM) issues for defense organizations, as electronic components constitute the building blocks of the company's products; components are used in electronic cards, electronic cards are part of assemblies used in final products. The unavailability of electronic components creates obsolescence problems when manufacturing and sustaining systems. As the design, time to manufacture, the planned support life, and unforeseen life extensions of systems span long periods of time in the defense industry, obsolescence of electronic components is often unavoidable. The term 'obsolescence' is also known as Diminishing Manufacturing Sources and Material Shortages (DMSMS- this acronym is used in the U.S. to refer to obsolescence) (Rojo, 2011).

Defense industry products have long lifecycles from concept to disposal, spanning 20 to 30 years. The scope of defense projects is large, complex, and rather costly. Thus, very often, they are termed 'mega-projects', or programs, often encompassing several interrelated projects. Moreover, as the development of these products involves multi-year projects, obsolescence problems occur not only during the in-field life of products, but also during their development, especially in terms of electronic component obsolescence. Therefore, organizations must have a systematic approach to manage obsolescence issues arising in these complex systems (Pobiak, Mazzuchi, & Sarkani, 2014).

As new electronic component technologies emerge, and as these components are put to use in more and more complex systems with particularly lengthy product lifecycles, it becomes imperative to monitor and maintain constant technical surveillance over the components used in defense industry products, beginning at the concept design phase and extending all the way to the disposal of the product, in order to foresee the effect of such developments on the obsolescence of components.

In addition to rapid changes in technology, regulations about environmental, health and safety restrictions on the use of certain hazardous materials found in electronic components, also called Restriction of Hazardous Substances (RoHS) compliance standards and requirements, have a significant role in the obsolescence of electronic components, further accelerating the need for changes which result in earlier obsolescence.

Moreover, long procurement lead times for electronic components cause prolonged delays in supply chain activities. When rapid changes in technology, or RoHS on electronic component occur, even when components begin their active status as they are ordered from the supplier, they can become obsolete before the supply chain activity is finished. Along with that, mergers and acquisitions of electronics companies shorten the lifecycle of electronic components, directly affecting supply chain processes for defense industry companies.

Hence, defense systems are vulnerable to obsolescence, resulting in extensive project delays and financial losses in the absence of appropriate obsolescence management ativities.  Equipped with effective OM capabilities, companies are able to foresee potential threats from the beginning of a product's lifecycle all the way to its disposal, and can react with proactive and/or reactive strategies, mitigation and resolution approaches. In that way, companies are able to minimize delays in projects and hence penalties, as much as they are able to mitigate the risks of obsolescence and minimize these risks encountered during project management, research and development (R&D), manufacturing and services, and supply chain management.

The obsolescence of electronic components must be taken into account from the beginning of a product's lifecycle, which is the concept design phase of defense systems. Obsolescence is also a major issue during the in-field life of these systems in relation to the warranty and maintenance contracts with customers. Throughout the lifecycle of defense systems obsolescence management is of critical importance affecting the sustainability of systems and related costs.

For companies in the defense industry, obsolescence management is one of the Critical Success Factors. Keystone companies in the defense industry heavily invest in obsolescence management and attach great importance to this issue. The ministries of defense of the United States (US) and the United Kingdom (UK) emphasize this issue by developing, adapting, and implementing international standards such as IEC 62402:2007 as well as BS EN 62402:2007 (IEC 62402:2007, BS, 62402:2007, JSP 886, 2012). Several leading companies in the defense industry, such as British Aerospace and Marconi Electronic Systems, Thales Aerospace, Selex Galileo, have OM related activities. Moreover, there are several organizations that work on obsolescence management, such as the UK Ministry of Defense Equipment and Support, the Joint Obsolescence Management Working Group, the Defense Logistics Agency of the United States Department of Defense, Naval Sea Systems Command, and Aeronautical Radio Incorporated, the Component Obsolescence Group (Rojo, 2011). Investments in obsolescence management directly affect the cost and time-effectiveness of projects, which can give rise to a competitive edge when bidding for defense systems.

## 1.2 Aim

The aim of this thesis is to propose an obsolescence management framework to mitigate and manage the obsolescence risk of electronic components in a large-scale defense industry company.

The framework targets the reduction of the negative impacts of electronic component obsolescence throughout the lifecycle of products, as well as the elimination of the communication and integration deficiencies in the company's existing obsolescence related processes. The elements of the proposed framework will enable the company to adopt proactive and/or reactive strategies, mitigation and resolution approaches to deal with obsolescence problems.

## 1.3 Scope

The focus is the company's electronic component obsolescence management related processes which are: project management, research and development, manufacturing and services, and supply chain management.

Electronic components constitute the largest group of items under threat of obsolescence. There are approximately 12,000 unique electronic components in the company. Electronic components are the building blocks of the company's systems, assemblies, and electronic cards which are used in multiple projects.

### 1.4 Thesis Structure and Outline

Chapter 2 presents the company background and projects, processes related to obsolescence management, electronic component categories, types of customer contracts, and the company's relationship with its electronic component subcontractors.

Chapter 3 covers the literature survey on obsolescence management in the defense industry. The literature covers publications from 2010 to 2018. The survey also covers past studies (1996 to 2010) due to their importance in pinpointing the emergence and effects of obsolescence management.

Chapter 4 presents the analysis of the company's current obsolescence management related processes, describing the workflow among these processes and the obsolescence problems encountered due to the lack of a formal OM process.

Chapter 5 describes the proposed obsolescence management framework developed in order to mitigate and/or resolve obsolescence management issues.

Chapter 6 presents an overview of the OM framework, its implications, and limitations, as well as suggestions for future work.

# CHAPTER 2

# OBSOLESCENCE MANAGEMENT OF ELECTRONIC COMPONENTS IN A DEFENSE COMPANY

## 2.1 Company Background

The large-scale defense industry company has approximately 5,000 employees, and works in different areas, which include communication and information technologies, microelectronics, guidance and electro-optics, radar and electronic warfare systems, defense systems technologies, transportation, security, and aerospace. Its annual revenue is approximately one billion dollars.

The company produces technologically advanced electronic systems. It is capable of prototyping, product development, sub-assembly, and final assembly of sustainment-dominated systems, including repair and maintenance services, as well as the provision spare parts.

Electronic component obsolescence problems often occur in military systems before being fielded; this is due to the fact that the development of these systems spans on average 8 to 10 years. Moreover, these systems nearly always experience obsolescence problems during their in-field life. The in-field life of most of these systems is expected to be around 30 years. Currently, the company does not have formal procedures and processes for managing obsolescence.

The company deals with intricate system designs, and these systems include hundreds and thousands of electronic components interconnected with different serial and parallel configurations. Moreover, these systems have high-performance requirements and are subject to military and avionics standards. These requirements are related to predefined specifications of military standards in design rules. These interconnected and complex systems are affected by obsolescence issues and are at high risk in terms of obsolete components. These risks can create problems for contracts in terms of time delays in delivery, as well as maintenance agreements after delivery. As a consequence, the company faces the threat of obsolete electronic components during development as well as during the in-field phase of products while providing maintenance and repair services.

## 2.2 The Company's Projects

The company is project-based, and every project ends as a system for the company. Its customers are mainly the military forces in the Republic of Turkey and abroad. The company has an Enterprise Resource Planning (ERP) system where all files and attachments are saved and shared within specific subfolders for each project. Documents and information on electronic components are included in the ERP. The company also has a Product Lifecycle Management (PLM) system, where some processes and documents are saved and shared within specific subfolders for some electronic card designs. Currently, not all projects are entered in the PLM system; therefore, not all electronic cards are in the system.

Currently, the company has approximately 100 projects. The company uses a wide variety of electronic components in its projects. For this reason, the management of the company's electronic components is conducted through registering them in electronic components libraries. There are two categories of libraries: the first is the library in the ERP system, the second category consists of a number of libraries that are part of Electronic Design Tools (ECDT) used by the company. These electronic card design tool component libraries (ECDTL) include the components that are in the ERP system’s database.

The company’s projects life cycle can be divided into six main phases, namely concept, assessment, development, manufacturing, in-service, and disposal (CADMID). Each phase of CADMID involves electronic components and the obsolescence of these components which have their own CADMID cycles, starting at different periods of time. This is described in detail in Chapter 3.

The company’s projects are multi-year projects, and, for instance, the design phase can take up to 8 years. Since the completion and system fielding take many years, the risk of the emergence of obsolescence problems is rather high during and after the design phase. Coupled with the phases of manufacturing and testing, the completion of a project is about 10 years. After completion, the electronic components of the projects are often exposed to obsolescence problems. Since the field life of projects is very long, approximately 20 to 25 years or more, obsolescence issues in electronic components constitute a considerable threat as the company is obliged to fulfill customer needs. In the following section, the company’s processes directly related to obsolescence management are described.

## 2.3 Processes Related to Obsolescence Management

The company's projects are managed by specific processes, which are project management, research and development (R&D), manufacturing and services, and supply chain management and their subprocesses as shown in Figure 2.1. Project management includes the follow-up of all processes related to the project, such as bidding, contract management, risk management, and configuration management. The R&D process includes system engineering, design, and safety and reliability subprocesses. The process of manufacturing and services includes production planning, delivery management, maintenance and repair services, evaluation of customer requests and complaints, and manufacturing inspection and other quality control processes for electronic components. The supply chain management process includes all types of material procurements and subcontractor management subprocesses. Electronic components are used in all of the company's projects and can be seen as the building blocks of the company's products when developing products.

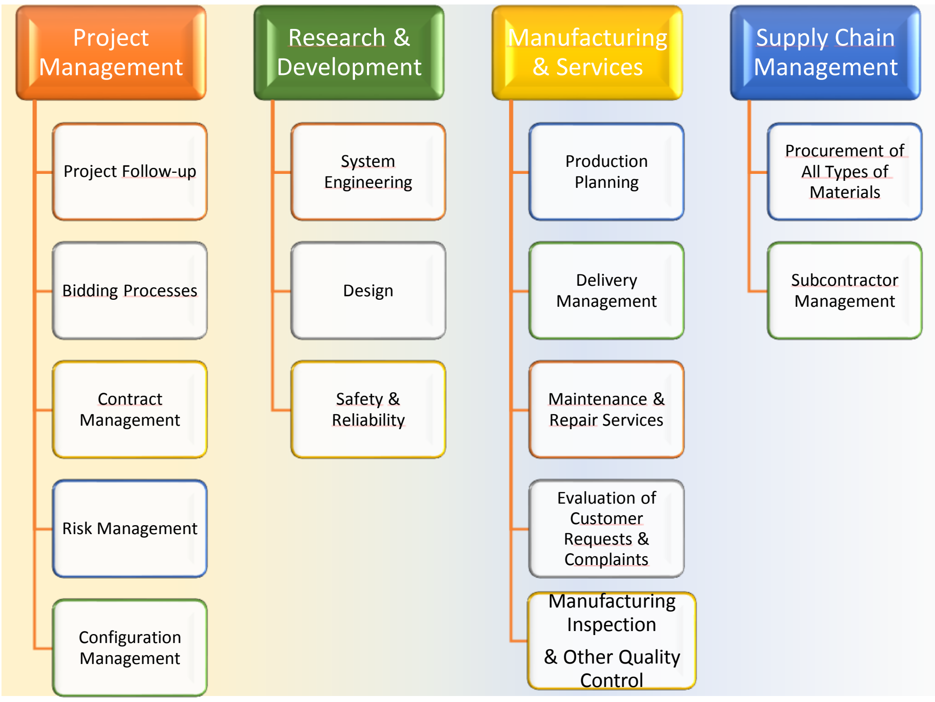


*Figure 2.1* Processes Related to Obsolescence Management

As mentioned above, the electronic components used in projects are available in two libraries: the company's ERP system and ECDTLs. The ECDTLs are constantly updated as new components are used, and/or existing components become obsolete. This is carried out by R&D under the design subprocesses. It is also important to carry out these updates when a new version of electronic design tools becomes available. But these electronic component libraries of the design tools are not overseen by a process owner who is related to obsolescence management. This means that other process owners can register new components in the ECDTLs without checking them against obsolescence, which makes the information on these components unreliable. The electronic components data are managed in an incompatible manner between the ERP system and the ECDTLs as well as the company's inventory. Moreover, some component data may be redundant due to multiple entries of components. There are also missing components when the ERP and ECDTLs are compared. There is no data integrity between the ERP system and the ECDTLs, nor the company's inventory.

In fact, the company has the necessary know-how to manage obsolescence; however, there are no formal procedures to this end. The Production, Planning, Procurement and Design Departments only react when an obsolescence problem occurs. There are no specific procedures for integrated OM activities. As will be discussed in Section 2.5, since there is no official obsolescence management process of the component lists among the four main processes, the know-how capability of the Design Department cannot be transferred to the other departments responsible for project management, manufacturing and services, and supply chain management.

The design subprocess begins once the projects have started, and the system requirements have emerged. After the design is complete, the necessary prototypes are formed, hardware and software verifications are completed, and the system tests are conducted, after which the manufacturing process starts. When manufacturing is complete, and all qualification tests are over, the products are ready for delivery. The systems are delivered to customers for use in the field. During the long lifecycle of projects, there are risks of obsolescence until project completion, however this risk is even higher after project completion, during the in-field lives of systems. This is due to the fact that the in-field life, requiring the provision of maintenance and repair services, is much longer than the project lifecycle.

The company also does not have a methodology or roadmap for establishing an optimum design refresh planning (DRP) schedule for electronic systems based on forecasted electronic part obsolescence. Determining the date of design refreshes in order to avoid future costs is the main purpose of DRP. It allows identifying which obsolete system components should be redesigned, and when the change should happen. The company needs a methodology and procedure for deciding the best dates for design refreshes, and what are the optimum reactive management approaches to use between each refresh. DRP is discussed in Chapter 3 under the strategic management of obsolescence.

The company's main processes (Figure 2.1) produce electronic component data such as component usage frequency, the number of components used in electronic cards, their preferred rates, the results of manufacturing inspections and other quality control data for components, alternative components to select in case of obsolescence, obsolescence data, logistical data such as supplier selection criteria, delivery lead time, and customs clearance.  These data can provide insights for future decisions when deciding on components of critical projects, or redesigning existing components as a result of obsolescence. As far as is known, there are no statistical analyses conducted using these numerous electronic component data sets produced during the company's processes. These data are crucial for DRP, and critical for the proactive management of obsolescence.

The sources of these data are contract management, risk management, and configuration management (under the project management process); design, and safety and reliability (under the R&D process); production planning, delivery management, maintenance and repair services, evaluation of customer requests and complaints, manufacturing inspection and quality control (under the manufacturing and services process), procurement and subcontractor management (under the supply chain management process). Further details are given in Chapter 4.

The performance of electronic components is controlled by the safety and reliability engineering process which provides technical support to the project management, design, manufacturing and services processes, by examining the electronic components' reliability in terms of conformance to failure rates, mean time to repair as specified in the technical requirements which come from project management. All Bill of Materials (BOM) that are used for listing the electronic components in the electronic cards of the system are sent to safety and reliability engineering to calculate the reliability of the system. When the results of the reliability analysis of the system do not meet the requirements, it is reported back to the design subprocess. Consequently, the designer can change the electronic component(s) in the BOM. The Safety and Reliability Department have all BOM lists, the data of the electronic components' reliability and the data of replaced components. The information about the replaced component (i.e. alternative component) includes the reason for the replacement and both the old and new component data. The Safety and Reliability Department is directly related to obsolescence management activities, and also monitors component changes in in-field products by following reliability analyses of that product, based on customer feedback while providing maintenance and repair services. However, there are currently no OM related studies using these data.

The Design Department supports the Production Planning, and Procurement Departments in order to find alternatives for obsolete components. The Production Planning, Procurement, and Design Departments are collaborating via e-mails when common component obsolescence problems occur. For instance, when obtaining the news of discontinuance or change notifications of components from suppliers [also known as product discontinuance notification (PDN) and product change notifications (PCN)], these departments communicate via e-mails about obsolescence mitigation and resolution activities. This communication is informal and does not ensure that the information reaches all related parties in time, nor is this information formally recorded.

There is no specific procedure or policy in the company to identify mitigation approaches to determine alternative components or alternative sources of supply for obsolete electronic components. Mitigation operations towards solving a problem of obsolescence are carried out after the problem occurs, and these problems usually emerge at unexpected times for the company.

### 2.4 Electronic Component Categories

The number of electronic components in the company is approximately 12000. These are recorded in the ERP as well as ECDTLs. The electronic components libraries can be divided into five main categories: integrated circuits (ICs), non-integrated circuits (Non-ICs), inductors, capacitors, and resistors, as shown in Table 2.1.

Table 2.1 *Electronic Component Categories*

| Electronic Component Category | Number of Components Recorded in Library | Number of Suppliers Recorded in Library |
|---|---|---|
| **ICS Category** | 3200 | 105 |
| **NON-IC Category** | 2100 | 98 |
| **INDUCTORs Category** | 1200 | 100 |
| **CAPACITORS Category** | 3000 | 100 |
| **RESISTORS Category** | 2500 | 100 |
| **TOTAL** | 12000 | 503 |

Furthermore, these component categories are sub-classified as passive, active, and electromechanical components. Passive components are resistors, capacitors, magnetic devices such as inductors, coils choke and transformers, PN junction diodes, potentiometers, transducers, sensors and detectors. According to their electrical characteristics, these components are low complexity components. Electromechanical components are also passive components. Due to their electrical characteristic, these components are categorized in another class. Electromechanical components are crystals, resonators, connectors, and switches. These components are classified as low complexity components. Active components rely on a source of external energy and include amplifying components such as transistors. Active components are integrated circuits (ICs) such as FPGAs, diodes such as photodiodes, Zener, schottky, light-emitting diode (LED) (diodes might be active or passive depending on their properties), transistors, logic gates, operational amplifiers, optoelectronic devices, vacuum tubes, discharge devices and power sources. These components are classified as high complexity.

FPGAs and LEDs from among the high complexity components are designated for use during the concept design phase. These components in fact carry a high risk of becoming obsolete and creating design problems in the future. Also, crystals and connectors from among the electromechanical components carry high obsolescence risks. Despite being among the low complexity components, connectors may require long periods of time to find alternatives when there is an obsolescence problem due to design requirements. It may even be impossible to find pin-to-pin compatible alternatives to these components depending on their parametric properties. Such cases would drag designs into re-designs.

The total number of suppliers for electronic components for all categories is approximately 503, as shown in Table 2.1. The number of suppliers is shown per category; some suppliers produce components for other component categories as well.

However, there are incompatibilities between the information of electronic components in the ERP system and in ECDTLs. For example, a component registered in the ERP system is not present in the ECDTL, and vice versa.

The ECDTLs and their categories are formed and managed by the Design Department, without any input from the safety and reliability engineering, system engineering, manufacturing and services, and supply chain management processes. This is a significant problem.

The company does not have an OM process based on the classification of these components or determining the obsolescence mitigation and resolution strategies covering all departments related to component obsolescence issues. The Procurement Department usually gets a Product Discontinuance Notification (PDN) from suppliers and informs the Production Planning Department, or sometimes the Production Planning Department receives a PDN from suppliers and informs the Design Department. However, the Design Department sometimes does not get this information due to the lack of communication between these departments.

There is a lack of communication between Production Planning, Design, and Procurement Departments in terms of component suppliers PDN and Product Change Notifications (PCNs). The technical knowledge of the Design Department about the replacement of obsolete components is often not shared with other departments as there is no single standardized library of electronic components, and there is no formal obsolescence management process. Therefore, other departments directly related to the obsolescence management of electronic components are not aware of the components' technical information as much as the Design Department in order to deal with this issue in their departments.

Furthermore, as mentioned above, the electronic component data are not used for statistical analysis, and this is another major problem for the company. Statistical analysis is required to organize electronic component libraries towards monitoring the frequency of usage of components in the company's products. This statistical analysis can contribute to the establishment of a standardization for components.

Most of the electronic components mentioned above consist of Commercial-off-the-shelf (COTS) components. The impact of COTS components is further explained in the next section.

## 2.5 Status of Commercial-off-the-Shelf Components in the Company

Commercial-off-the-shelf (COTS) components are designed for commercial products such as PCs. Its manufacturers determine and control their performance, configuration, and reliability, including design, material, process, and testing specifications without customization for users. COTS components are ready-to-use hardware products, and highly available in the commercial electronic component market. The company's power on the supply chain for COTS electronic components is weak, as these components become obsolete rather quickly because of the conditions in the commercial electronic market as discussed in Chapter 3. Thus, using COTS electronic components in the company carries risks. Due to this, it is recommended that the company makes partnership agreements with its suppliers in order to guarantee critical COTS component support. The company may engage in partnership agreements or in expanded partnerships (such as for high complexity components) with COTS suppliers through contracts. This plays a key role especially when an electronic component cannot be found in the market, or suddenly becomes obsolete due to a market strategy determined by its manufacturer. Through partnership agreements, the supplier may keep the component in its inventory for an agreed period of time. In this case, the price of the obsolete component is much higher than its original price, due to the fact that the supplier agrees to keep excess inventory, and hence incurs inventory holding costs. The company can do this for its critical, frequently used components. In order to determine which components are critical, the company needs to analyze electronic component data. However, currently, the company does not monitor and evaluate COTS components' obsolescence situations in order to develop appropriate partnership agreements with its suppliers. Partnership agreements with suppliers are not based on the data of the COTS components' statistical analysis.

The following section discusses how all electronic components, including COTS components, are being monitored in the company's designs.

### 2.6 Monitoring Tools for Bill of Materials

The Bill of Materials (BOM) contains detailed information on parts (electronic and non-electronic) used in the company's designs. BOMs are included in the Circuit Card Assembly (CCA) document. Updated CCA documents are vitally crucial for the company's processes. This vitality is justified with for example changes in component manufacturer names due to acquisitions or keeping Manufacturer Part Numbers (MPNs) up-to-date in order to update these information in CCA documents for BOM components affected by changes of electronic components in the market. System delivery times are also directly related to the lead times of BOM components (logistical data). Control and review of BOMs in terms of sustainability and supportability of the system design, procurement, and manufacturing is crucial for obsolescence management.

During design, components are selected according to industry standards by hardware design engineers. Besides, there is an obsolescence prediction tool for monitoring and controlling BOMs in the Design Department. The Design Department uses the electronic component data and BOM obsolescence monitoring software tool to manage the BOM, monitoring and controlling the electronic component library, offering some customization properties such as the recommendation of alternatives for obsolete electronic components. On the other hand, the electronic component data and the software to manage BOM are not used in the manufacturing and services nor in the supply chain management processes. The manufacturing and services as well as the supply chain management processes obtain the information for monitoring obsolescence and alternative components from distributors, suppliers, and manufacturers of components. Besides, the Manufacturing and Services as well as the Supply Chain Management Departments get the information of BOMs obsolescence analysis from the Design Department only when they ask via e-mails. Since there is no standardized procedure throughout the company, these departments are not always informed about the obsolescence of components if they do not ask the Design Department. These departments are generally informed by supplier and distributor notifications, or Original Equipment Manufacturer (OEM) and Original Component Manufacturer (OCM) notifications.

## 2.7 Customer Contracts

This section discusses the types of contracts implemented in the in-service phase (in-field life of systems) and how components of projects are managed in line with these contracts between the company and its customers. Additionally, warranty types included in contracts are discussed below.

There are four types of contracts for the company's in-service phase. The first type is the main contract in which the scope of the warranty period is included in the clauses of the contract. The company is liable to keep its products in working condition and provide after-sale services, including repairs and upgrades to its customers as stated in each main contract. In addition to the main contract warranty clauses, there can also be additional contracts to extend the warranty. Contracts with their warranties extended can be undersigned to extend the warranty at the beginning of the main contract, or before the end of the warranty, or after the warranty expires.

The second type of contract is support-logistics contracts, and such contracts are undersigned for repair and maintenance services to provide support to devices owned by customers in case of failure, or maintenance of the devices. The maintenance and repair services provided to the customer in such contracts may also apply to the system that the company has previously sold to the customer or to the system that the customer receives from other original equipment manufacturers (OEM). This second type of contract can also be prepared according to the condition and scope of the type and size of equipment failure. Besides, the company's maintenance services are not often included in the main contract but can be covered by support-logistics contracts based on the types of service requirements. Support-logistics contracts, all types of services related to repair and maintenance are made explicit to address needs for critical response to devices owned by customers. Technical support, spare parts and repairs of contracted systems are included in support-logistics contracts. While providing maintenance and repair services, the solution can be proactive, since the electronic components of contracted systems are stated in the contract. Support-logistics contracts transfer the risk of obsolescence to the customer, since when obsolete components are identified by the company during maintenance and repair services, the customer accepts long lead times, high prices, and even the payment for redesign services in order to overcome the obsolescence problem.

The third type of contract covers case-by-case failure applications, which means the company also contracts for never-encountered failures. There is no limited scope in such contracts. Thus, failure is a unique status for both parties, the company and the customer. According to the condition of the failure, contracts can be made per component or per device. A large percentage of the risk in such contracts belongs to the customer. The reason is that in cases of failure, the customer agrees by this type of contract to pay for services towards a resolution to be provided by the company. The fact that the risk belongs to the customer means that the higher the risk, the higher a cost the customer will face.

The fourth type of contract is performance-based logistics (PBL) contracts. PBL contracts, the type of contracts that have become widespread in the defense industry in recent years, are used by the company less frequently compared to the types described above. These contracts are also known as capability availability-based contracts, which cover entire systems. With regard to these contracts, the customers pay not only for the systems, spare parts, and repairs and maintenance services, but also for the performance of the system (determined under the contract) during its field life. The customer wants to ensure that the systems meet their competency target (or in other words, delivery’s usability and capability goal) during their performance in the field in their main area of usage, and do not fall under the defined competency target. Thus, the customer does not only purchase the product, but also the product's performance. During the long-term operational field life of military systems, the system's performance in the field is expressed as a percentage or proportional metrics in the clauses of PBL contracts. The company is obliged to provide the safety and reliability requirements as well as ensure that the competency target in terms of performance is met. For example, if one of the clauses of the contract is: "During the in-field life of the systems, 99 percent of the systems shall be fully operational without any error," the company must provide support so that the systems are operational at least 99 % of the time in the field.

In terms of after-sale services provided during a system's in-service phase, all types of contracts cover after-sale clauses, stating that the company must supply spare parts and direct its professional service team to its customers. The company has high sustainment costs which include the costs of maintaining, and supporting a fielded system with a long field life because of the nature of military systems. The contract clauses indicate that necessary measures are to be taken regarding occurrences of obsolescence, when last time buys will be made, and when alternative components will be developed to replace obsolete components in systems. Since the company does not have a specific obsolescence management process, it cannot foresee the scope of obsolescence, and cannot estimate the approximate net present values (NPV) of contract costs. Consequently, the cost of these contract clauses and the obligations undertaken by the company can be much higher than expected.

For all these types of contracts, the company is obliged to provide its customers support for maintenance and repairs during the warranty period in the in-service phase. There is a warranty clause in all contract types. The warranty type used by the company is classified as a 'failure-free' warranty or zero-error warranty. Almost every contract of the company includes a failure-free warranty clause and the company undertakes all maintenance and repair tasks no matter what the malfunction might be in the system (except user errors) throughout the warranty period, which is a minimum of 5 years.

For this reason, the company must take the necessary measures against possible obsolescence problems of electronic components that may arise during the warranty period. Further, if maintenance costs are estimated realistically and future risks are foreseen, much lower costs of warranty will be reflected. These estimations will enable the company to offer lower prices during bidding processes. However, with the existing high deviation of warranty cost estimations, any low-price offer for a product during the bidding process will mean that the company will have to perform maintenance repairs at high costs.

As mentioned above, companies in the global defense industry have recently shifted towards performance-based (PBL) contracts, and obsolescence management of electronic components in these contracts has gained greater importance. The company's PBL contracts are hinged upon the performance of systems that are vulnerable to obsolescence in the field. However, the company does not have an established infrastructure for PBL contracts. In PBL type contracts, comprehensive and detailed performance studies and analyses are required for high-reliability products. The risk for the customer is low, whereas the risk for the company is very high in this type of contract. Having high-reliability performance in products raises costs, which heavily influences the chances of winning the initial bidding process for a project. Therefore, a detailed obsolescence management plan coupled with reduced maintenance cost for products, and the measures to be taken against future obsolescence related problems can significantly reduce the total product cost. Moreover, the estimation of obsolescence of electronic components and finding alternative components play a key role in reducing total product costs. These can also lower the final offer to a great degree when bidding. With these efforts, the company as a contractor will better foresee future risks, take necessary measures, and carry out contingency plans for these risks methodically. Consequently, the company will be able to provide the high-performance criteria defined in the PBL contract for the customer.

Another point for contract management is that a breach of contractual obligations can lead to severe penalties. Penalties are monetary or can lead to contract termination in terms of sanctions for violations in law when failing to fulfill contract clauses.

The costs incurred, including penalties, can be much higher than the original purchase price of the product. The cost of obsolete components, or the cost to redesign could exceed the original price of the product or the component. Costs for requalification and costs for recertification can also be incurred when using alternatives for obsolete components. In the case of failures caused by electronic components, if the electronic component is already in the company's inventory, a requirement to replace the component provided under the maintenance services will not cause a high cost. However, when the component to be replaced cannot be found in the company's inventory or in the market, the time spent during the search for an alternative component is added to the cost of engineering services. Besides, if requalification and recertification are mandatory for the new component to replace the obsolete component when proactive solutions are not applied in time, providing such solutions to the customer may exceed the original price of the product sold. Moreover, a reactive approach will cause delays for the customer, since the necessary service cannot be provided in time. Also, these delays may be subject to penalties under the terms of the contract.

Providing low-risk resolutions to the customer by applying an obsolescence management plan is as valuable to the customer as it is for the company. Effective obsolescence management can decrease the risks related with failure to fulfill contract requirements, while at the same time directly increase the efficiency of business processes within the company. The optimization of a maintenance policy requires the prediction of the failure rates in a system. The company has a safety and reliability engineering subprocess for the prediction of failure rates; however, this subprocess should ideally be integrated with an obsolescence management process in order to be effective.

## 2.8 Relationship with Subcontractors

The company uses subcontractors for some of its electronic components and guides them in their manufacturing processes. However, no specific rule or procedure regarding OM is applied. During manufacturing the company lends components to its subcontractors when necessary. The subcontractors use these components, and subsequently return these components to the company when they obtain the components from their suppliers.

The company's CCA documents containing the BOM lists are given to subcontractors. However, electronic components, lent or listed under the BOM lists, sometimes become obsolete. When a subcontractor experiences a shortage of components, for example, due to obsolescence or unavailability of supplies resulting from long lead times from the market, the company provides obsolete components or their alternatives from its own inventory or purchases those components from its suppliers to give to its subcontractors. These processes are not formally controlled or followed by specific procedures, and data about these processes are not utilized to give insights for other occurrences in the future.

If there were an obsolescence management process, it would reduce the risks of obsolescence and project delays that might occur with the company's subcontractors. Alternatively, at least, it could have previously predicted the risks of component obsolescence and provided earlier assistance to the subcontractor to eliminate project delays. Nonetheless, the company and its subcontractors do not have a specific procedure, policy, or guideline on OM for the management of electronic components among themselves.

The following chapter presents a literature survey on the advantages and challenges of obsolescence management.

# CHAPTER 3

# OBSOLESCENCE MANAGEMENT APPROACHES

## 3.1 Introduction to Obsolescence

Managing the obsolescence of electronic components in the defense industry requires an organization to have control over its supply chain. This is in part due to the extreme length of manufacturing and support processes, as well as the nature of developing defense systems. Obsolescence management is needed to better forecast sustainment costs during the lifecycle of defense systems (Sandborn, 2013). In this chapter, several approaches to planning and managing obsolescence are described with a review of the literature for the purpose of establishing a framework on drivers of obsolescence for companies in the defense industry.

Different terms are used for obsolescence in the literature. These include Diminishing Manufacturing Sources and Material Shortages (DMSMS) as used in the US, and the term obsolescence is used more often in the UK.

The phase of obsolescence in an electronic component begins after the information about its discontinuance is published, and the electronic component is regarded as obsolescent as shown in Figure 3.1.

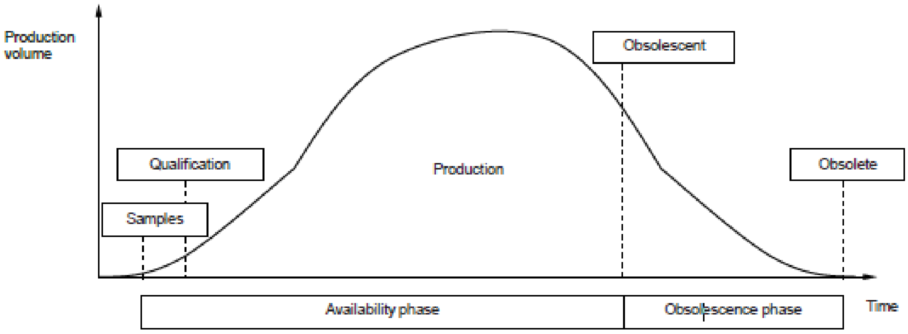


*Figure 3.1* Availability Phases of Electronic Components based on Production Volume (BS EN 62402:2007)

According to the British Standard BS EN 62402: 2007, as soon as the information regarding discontinuance of a component is published and information of obsolescence for a component is issued through the product discontinuance notification (PDN), end-of-life (EOL) notification or life-time buy (LFTB) notification, the obsolescence phase of the component begins. Moreover, a product change notification (PCN) issued by the original equipment manufacturer (OEM) or original component manufacturer (OCM) also initiates the product's obsolescence phase (BS, 62402:2007).

## 3.2 Electronic Component Lifecycle Phases and Project Lifecycles for Obsolescence Management

An electronic component's life cycle is defined under six lifecycle phases which are introduction, growth, maturity, decline, phase-out and lastly obsolescence also known as discontinuance (Meyer et al., 2004; Meng et al., 2012). The introduction phase of an electronic component launches the new product into the market and samples are then available, while final qualifications of a new electronic component may be in progress as shown in Figure 3.1 during the initial stages of the availability phase. The growth phase of the electronic component is when sales of a product are increasing, and the OEM or OCM can begin to benefit from economies of scale in production and profit margins. The maturity phase often involves competition among the OCMs, and for this reason, modifications or improvements on the electronic component may occur during this phase in order to maintain competitive advantage in the market. With the beginning of the decline phase, the production volume of the component begins to shrink due to saturated market conditions or technological advances. During decline, the obsolescence phase begins.

Even though the obsolete electronic component might be available from aftermarket sources, it is quite risky to use. One of those risks is the danger of purchasing counterfeit components from these aftermarket sources. The most significant problem of Diminishing Manufacturing Sources and Material Shortages (DMSMS) is the existence of a pre-determined procurement life, or in other words the availability phase, of the component from its original manufacturer within a specified period. In some cases, this period may be less than one year (Sandborn, 2013). For a component to have less than a lifecycle of one-year means that these components are in the phase of their Last-time-Buy (LTB), or are not recommended for new designs (NRND). Suppliers notify their customers with PDNs, LTB, or NRND notifications about the unavailability of components.

In each lifecycle phase, any kind of electronic component can have a different life cycle progression with a different rate of completion. Some components may remain in the maturity phase for 5 years, while others may become obsolete within 12 months (Sandborn, 2013; Meyer et al. 2004). Considering this, while the system itself is still in its early lifecycle phase, some of its electronic components may have already reached the obsolescence phase. Along with that, the obsolescence rates of components and of the system are different from one another, and as a result, this can lead to severe risks for companies, especially for those in the defense industry (Meyer et al., 2004).

Lifecycles of electronic components can be categorized under the lifecycles of other systems, as systems are formed by combinations of electronic components. In order to understand, represent, and manage the life cycle processes of systems in addition to the lifecycles of components within systems, the term “Concept Assessment Demonstration Manufacture In-service Disposal (CADMID)” is used (Figure 3.2). The term CADMID was first coined in Britain during the ‘Smart Procurement’ initiative program aiming at better specifying the expected performance, cost, and time parameters from projects in the defense industry (UK Ministry of Defence, 2006).

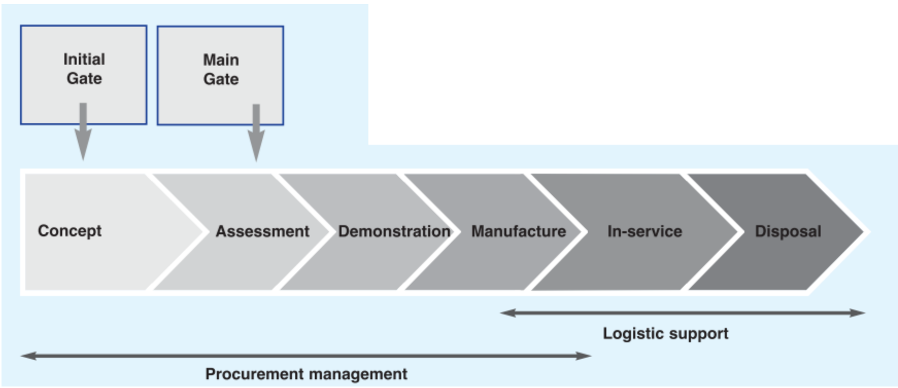


*Figure 3.2* CADMID Cycle (UK Ministry of Defence, 2006)

According to EN 62402: 2007 standards, lifecycles of projects can roughly be defined by phases in CADMID cycles. Steps in projects for managing obsolescence under the CADMID cycles of systems and product lifecycles of components are summarized in Figures 3.3 and 3.4. Figure 3.3 demonstrates how the processes of obsolescence management can be mapped to the product lifecycle phases. Figure 3.4 details the obsolescence management processes shown in Figure 3.3. The process includes the provision of economical and applicable supply and support activities in replacing components as well as planning coordinated activities throughout a product's lifecycle (BS EN 62402:2007). In every project, each CADMID cycle may involve different types of electronic components, and the obsolescence of these components which have their own CADMID cycles, starting at different periods of time. Thus, it is crucial to evaluate and monitor the current electronic component lifecycle in projects based on the intended lifecycle of the entire project.

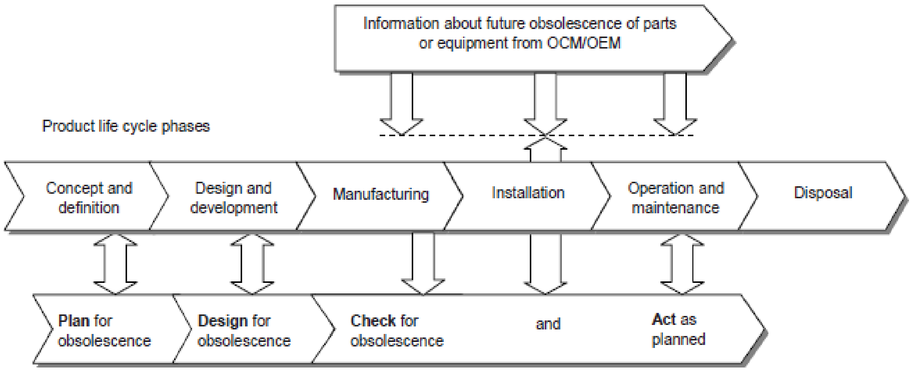


*Figure 3.3* Process Steps in Obsolescence Management Applied during the Intended Lifecycles of Products (BS EN 62402:2007)

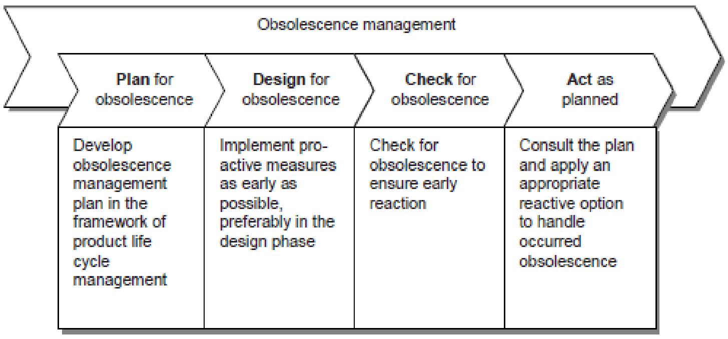


*Figure 3.4* Demonstration of OM for Intended Product Lifecycle (BS EN 62402:2007)

Obsolescence management must be viewed from both sides of the supply chain; the user and the supplier as shown in Figure 3.5 (BS EN 62402: 2007). In order to ensure a reciprocal benefit for both sides which are the OCM (the supplier) and the OEM (the user or the manufacturer of the product), obsolescence management responsibility lies with the OEM but ideally in communication with the OCM according to British Standard 62402:2007.

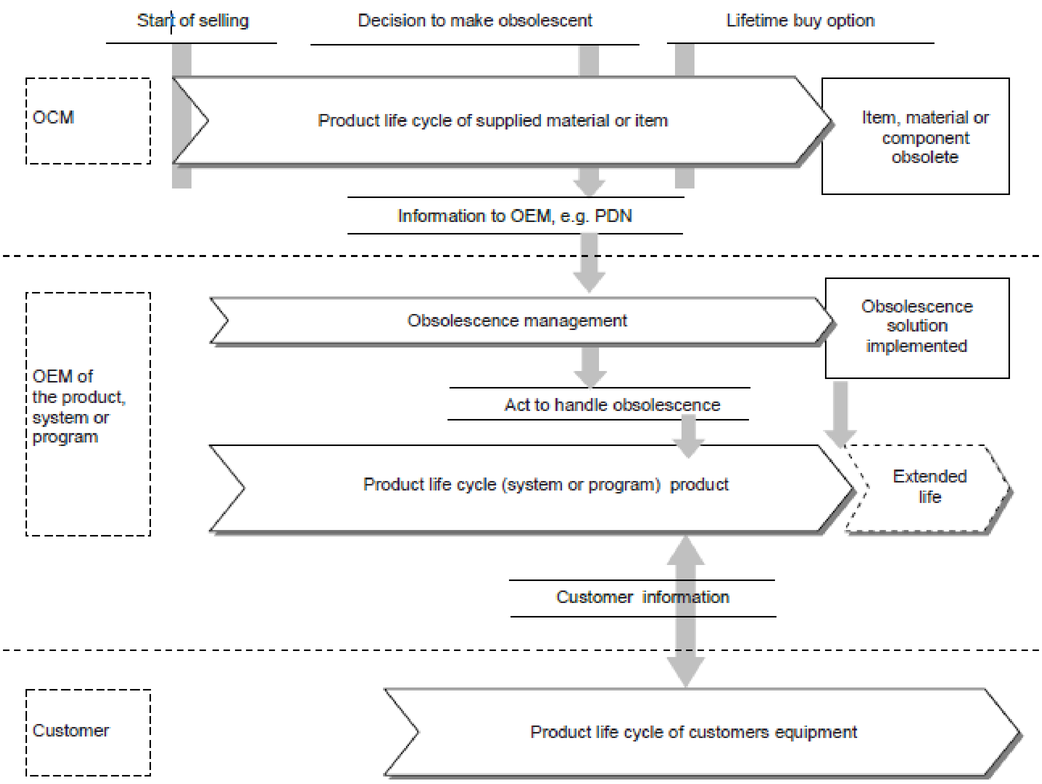


*Figure 3.5* The Obsolescence Management Relationship between Supplier (OCM) and Users (OEM and the Customers) within the Supply Chain (BS EN 62402:2007)

As can be seen in Figure 3.5, when the OCM decides to designate a component as obsolescent, the OEM is informed by a PDN for the LTB option. On the other hand, the OEM applies obsolescence strategies according to the obsolescence management plan (OMP) of the product lifecycle based on PDNs. At that point, the OEM informs the customer within the framework of the OMP. This information includes repair, maintenance, and support services to be provided by the OEM to its customer within the scope of their contract, as well as actions to be taken against future obsolescence situations.

### 3.3 Obsolescence Perspective of Managers

The problem of obsolescence is usually not fully understood or is not known by executives and designers in terms of methods to deal with it (Rojo, 2011; Meyer et al. 2004; Howard, 2002). Thus, after the occurrence of a problem of obsolescence, managers often solve the problem either in a reactive manner, or by implementing “quick-fix” solutions to the problem (Rojo, 2011; Meyer et al., 2004). As understood from these studies, it is crucial to intervene before an obsolescence problem occurs. It is strongly recommended that obsolescence mitigation and resolution approaches are implemented proactively and applied to all relevant projects in order to reduce obsolescence problems (Rojo, 2011).

Besides, there is another management issue that must be taken into consideration. Engineers complain to program-level management about technical and logistical problems in electronic components on a daily basis. These problems, most of the time, involve lead-free, tin whiskers, counterfeit and obsolescent components during supply. However, until the risks related with such complaints are evaluated and a quantitative analysis is made, or until a major catastrophe occurs, management often does not take any action (Sandborn, 2013).

According to Sandborn, there are two questions which are asked by staff at management level in order to identify to what extent resources should be allocated for obsolescence management. The first question is “Has a serious event occurred as a result of this problem (loss of life, equipment, or mission)?”, and the second question is “What is the likely future impact of this problem on me if I don’t take action (e.g., in terms of cost and/or availability)?” (Sandborn, 2013). These two questions are quite important for the management to create and implement OMPs in order to mitigate risks in projects.

Besides, the focus of production and design processes must be on high-value components to ensure that there is always an alternative within reach. Furthermore, the components used in systems should be as standardized as possible, and systems should be as modular as possible, thus increasing the availability status of electronic components.

The next section describes the causes and effects of obsolescence, while also discussing its significance with examples from the world's leading defense projects, emphasizing the importance of management's role in dealing with this issue.

### 3.4 Causes and Effects of Obsolescence

The problem of obsolete parts going unnoticed in systems contributes to the early disposal of military systems. For example, the majority of components and electronic cards of the Defensive Management System of the B-2 stealth bomber, which first took-off in 1989, were discovered to have gone obsolete in 1996. The B-2 program officers estimated that a budget amounting up to 21 million USD was needed for the re-design of several circuit boards and the repair of the system in addition to the replacement of the obsolete integrated circuits on the cards. Another option was to spend up to 54 million USD for the original main contractor to replace the entire system (Sandborn, 2008). According to the US Department of Defense (DoD), obsolescence plays a crucial role in military systems, and it is challenging to supply the parts needed to build or repair them (Geng, Dubos, & Saleh, 2016). According to US defense logistics sources, which include the DMSMS Guidebook, the F-16 program spent a total of $500 million to redesign an obsolete radar system (Meyer et al., 2004; Sandborn, 2008).

Moreover, an estimated $10 billion a year is spent by the US Department of Defense in order to manage obsolescence issues and mitigate obsolescence problems in systems (Sandborn, 2008). As seen from the above examples, one of the main reasons of obsolescence is time, and the obsolescence of components can cause massive costs and time losses when not monitored or noticed in systems.

The fact that the military systems must work in a way that is almost close to perfect, they are affected the most by obsolescence problems. Furthermore, after very long design and testing stages, they are expected to have a very long field life. These types of products only meet the investments returns when they have been in the field for more than 20 years.  As an example of this situation, even though some of the electronic parts become obsolete, some of the aircraft projects under the US Air Force are expected to have an average filed life of more than 30 years by 2020 (Sandborn, 2008).

Another important cause of obsolescence is that the expected market availability for chips is between 2 to 5 years. Moreover, the number of transistors on chips doubles every 18 to 20 months, according to Moore's Law (Sandborn, 2008). Moore's law was first put forth by Intel's founder Gordon Moore. It predicts that the number of transistors placed on a single square inch of the integrated circuit chip would double every two years (Figure 3.6). Thus, weak and inefficient planning in the management of electronic components can lead to unforeseen expenditures to combat the effects of obsolescence. Naturally, this would mean fewer financial resources for new investments in the future for the company, creating huge maintenance costs and delayed upgrades (Sandborn, 2008).

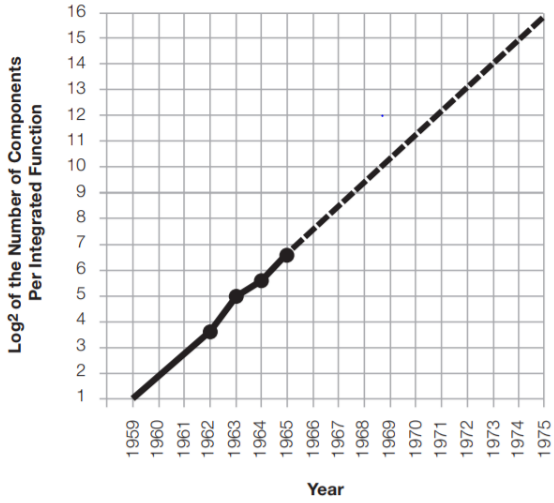


*Figure 3.6* Demonstration of the number of transistors doubling every two years (Moore, 1965)

Figure 3.7 shows forty-two years of microprocessor trend data from 1970 to 2020 and as can be seen Moore's Law still applies.

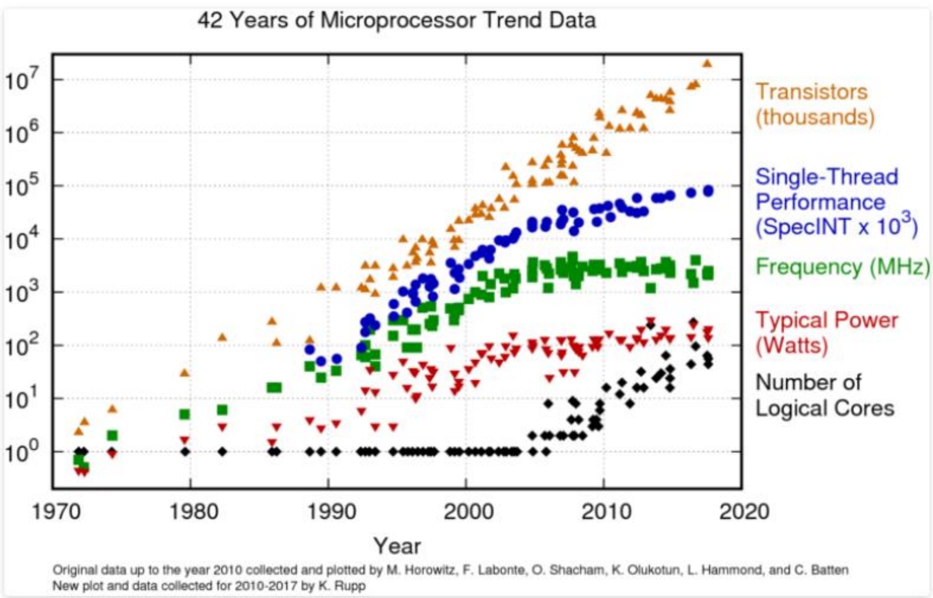


*Figure 3.7* Microprocessor Trend Data 1970 to 2020 (Karl Krupp, 2018, last accessed 2019)

Looking at the economic effects of Moore's law, it is emphasized that there is a rapid technological transition from microelectronics to nanoelectronics parts and that nanotechnology, an industry segment with exponential growth, triggers very rapid reduction in costs. This transition has also led to an increased interest in new areas, including new optimization technologies for nanotechnology materials and semiconductor production. Despite reports that the law "slowed down", it continues to be the industry's widespread torchlight (Investopedia, accessed 2019).

Yet another economic impact of the obsolescence of electronic components is that, with the end of Cold War, the U.S. defense industry turned towards commercial-off-the-shelf (COTS) components to save money (Sandborn, 2008), because military specification electronic components are more expensive than COTS components. The Pentagon turned to producers of COTS electronic components for their military systems. U.S. authorities began to pursue a policy of acquisition reform, and with this reform, military systems were designed and manufactured with at least 90 percent COTS components (Sandborn, 2008). It must be noted that COTS components enter the obsolescence phase faster due to the highly competitive environment in the consumer product market, as discussed the next section.

### 3.5 The Role of Commercial-off-the-Shelf Components in Defense Systems

To compete in and maintain the rate of market occupancy, as well as competitive advantage, the COTS manufacturer must improve its products for the consumer market. There is always the need to adopt the newest components, materials, or processes in designs for advanced technologies, with product redesigns remaining among the possibilities (Meng et al., 2012). Due to this, COTS components are directly affected by the rapid technological changes in the consumer market, so they have fast-changing and short product life cycles. Consequently, the ongoing and highly competitive environment in consumer products causes the obsolescence cycle for electronic components in the defense industry to become more visible (Meng et al., 2012). In most cases, most of the COTS electronic components become obsolete before the systems are fielded due to the long design cycles in the defense industry. As stated by Sandborn, the fielding and support of defense systems can take 20 years or more (Sandborn, 2013).

The obsolescence problem in avionic and military systems is considered to be very critical in terms of identifying system risks by the DoD of the US, UK, and Australia as well as NASA. COTS products are used to reduce obsolescence problems in the defense industry. NASA's Orion Spacecraft engineers define the obsolescence problems as a "huge challenge and the biggest problem" they deal with, while their spacecraft avionic products have a lifecycle of 30 years with electronic components becoming obsolete in four to six years (Michale, 2008; Geng, Dubos, & Saleh, 2016).

One of the cornerstones of electronic component obsolescence was that the European Union (EU) banned the use of lead material in electronic components in 2006. Although military and avionics systems are not included in the ban, it ignited problems and obsolescence issues for the defense industry. From the beginning of the EU lead-free policy, COTS manufacturers of integrated circuits (ICs) removed lead from their components (Sandborn, 2008), which had a direct influence on electronic systems in the defense industry. The prominent reason behind the change of policy is that lead-free alloys are cheap and have comparable appropriateness to lead in terms of mechanical, thermal, and electrical characteristics. However, lead-free alloys tend to sprout tiny whiskers over time, potentially causing short-circuiting compared with traditional solder which includes lead (Sandborn, 2008). The transition to lead-free electronic components resulted in the obsolescence of many COTS and military unique (mil-spec) electronic components used in defense systems. Therefore, the trend towards lead-free alloys should be closely monitored by the defense industry.

The defense industry has lost its influence on the supply chain for COTS electronic components (Sandborn, 2007; Feng et al., 2007). Marshall & Lambert (2008) also indicate that: "Obsolescence is often considered to be linked to the technological life cycle of components. Since technology has changed significantly compared to 30 years ago, the life cycle for commercially off the shelf (COTS) components obtained from suppliers is between two and three years". The management of COTS components requires a risk management perspective in the defense industry. The impact of this dominating influence of consumer electronics products creates additional risks to the defense industry. An example is discussed in detail under the "The Company's Sub-Contractors and Electronic Component Relationship" in Section 2.8 in Chapter 2.

There are different strategies at different levels of management related to the mitigation or resolution of obsolescence while monitoring designs or developing strategies required for effective obsolescence management. The following section presents literature definitions of various methods at different levels of obsolescence management.

### 3.6 Proactive, Reactive and Strategic Obsolescence Management Levels

In Sandborn's 2013 article titled "Design for obsolescence risk management", the three different levels of OM are summarized, as shown in Figure 3.8.

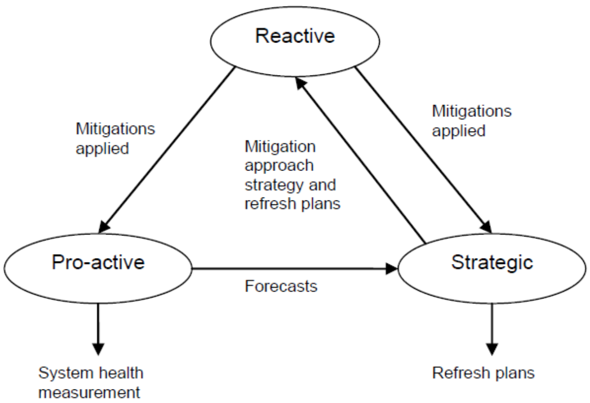


*Figure 3.8* "Three Levels of Obsolescence Management" (Sandborn, 2013)

The first OM level is reactive, where resolution approaches for obsolescence problems are carried out. The goal of reactive management is providing prompt solutions to obsolete components (Sandborn, 2013). Rojo also highlights that in the application of a reactive strategy, there is no prior action about the component before the need arises in the system (Rojo, 2011).

The second OM level is proactive management which requires the identification of critical parts. In order to minimize future obsolescence problems, component selection methods are applied in the design process and form the basis of a proactive strategy. Critical parts are classified into three main categories as follows:

1. At risk of becoming obsolete,
2. Will have an insufficient quantity of components after obsolescence to meet expected demand, and
3. Will represent a problem to manage if/when they become obsolete.

After the identification of critical components, their actual events of obsolescence are prioritized. The ability to forecast the risk of obsolescence of components is indispensable for a proactive management strategy.

The third OM level is the strategic management of obsolescence, using obsolescence data, logistics data, technology forecasting, and demand forecasting, also known as business trending. Strategic management of obsolescence allows strategic planning, life-cycle optimization, and long-term business case development for system support. Design refresh planning (DRP) is the widespread approach for the strategic management of obsolescence. It enables the designation of the set of design refreshes that minimize future costs (Sandborn, 2013). It is also essential to understand the importance of re-configurable systems and modular replaceable designs to support design refreshes (Meyer et al., 2004). DRP would be impractical if applied to every system in a company. The changes in technology insertion roadmaps, the system's functionality and performance over time must be considered when determining in which systems of the company DRP should be applied.

The next section describes mitigation strategies and resolution approaches for OM.

### 3.7 Mitigation Strategies and Resolution Approaches for Obsolescence Management

Rojo (2011) recognized in his studies that it is important to make a distinction between the terms ‘mitigation’ and ‘resolution’ which are often used interchangeably. The term mitigation is used to refer to minimizing the effects of obsolescence, or minimizing the possibility of obsolescence. On the other hand, the term ‘resolution’ is used to refer to resolving an obsolescence problem once it arises.

When identifying the mitigation strategies and resolution approaches for obsolescence management, studies demonstrate that it is essential to manage obsolescence in the design phase in a proactive manner (on the basis of a proactive OM level). It is strongly recommended by several studies that mitigation strategies in obsolescence management must be implemented in a proactive manner in all projects (Singh et al., 2002; Meyer et al., 2004; Josias et al., 2004; Torresen and Lovland, 2007; Rojo, 2011). The analyses of obsolescence shown in Figure 3.9 reveals the effects of proactive versus reactive OM in terms of how the evolution of the levels of obsolescence differs between proactive and reactive management over time (Rojo, 2011).

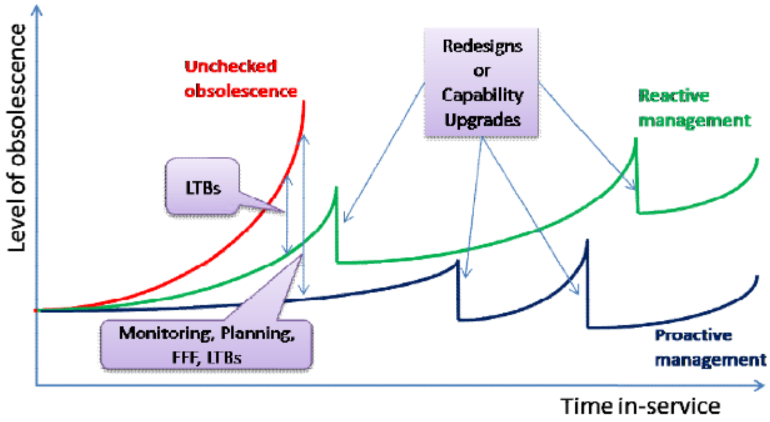


*Figure 3.9* Evolution of the levels of obsolescence based on the obsolescence management approach (Rojo, 2011)

On the other hand, there is no clear exact mitigation or resolution strategy. Firms should primarily identify their needs and then tailor their processes according to the most appropriate strategy for themselves. In Figure 3.9, the graph shows how the evolution of the level of obsolescence progresses based on whether obsolescence is unchecked, managed reactively, or managed proactively. As can be seen, for unchecked obsolescence, the level increases steeply in a short period of time. When the proactive management is applied, obsolescence does not reach very high levels. The comparison between the unchecked obsolescence and proactive management is based on monitoring, planning, Form Fit Function (FFF) replacement, and LTB mitigation strategies. While applying reactive management strategies, it can be observed that the obsolescence level is higher compared to when proactive strategies are applied. The underlying reason is that a reactive management strategy is applied after obsolescence problems occur. In the broader sense, the level of obsolescence has already increased in such a scenario. A company's capabilities in redesign, upgrade, and management of data on electronic components enable it to decrease the level of obsolescence. With redesign or capability upgrades, a company can efficiently intervene in sudden increases of obsolescence by applying reactive and proactive management strategies. When this happens the level of obsolescence drops.

Moving forward, obsolescence is a critical challenge for companies to meet their annual business goals, taking into consideration the fact that long-life products face the consequences of obsolescence much more frequently, especially in specific components of any given system. Such components are sometimes manufactured by the company that uses them, or are procured from other companies in the defense industry. In light of these circumstances, Sandborn et al. (2011) claim that “The fundamental disparities in life cycle needs and business objectives impose inevitable obsolescence challenges. Many long field life products particularly suffer the consequences of electronic part obsolescence because they have no control over their electronic component supply chain due to their relatively low production volumes.”

There are certain models and tools such as Silicon Expert (Silicon Expert, 2019) and IHS (IHS/Part Intelligence 2019) that estimate electronic component obsolescence and are used to tailor mitigation strategies for a company in order to replace such obsolescent components with newer technologies. Such models come from the field of electronics, and are also utilized in other sectors as well. These models are used to predict obsolescence, and apply mitigation strategies (Kidd and Sullivan, 2010).

It is also essential to understand that the level of obsolescence is quite a significant factor in deciding on the implementation of a mitigation strategy. The level of obsolescence is determined by the probability of the component’s obsolescence and its resulting influence over costs. An initial assessment of obsolescence probability for a component and its costs helps to determine the level of “proactiveness” which needs to be met at the component level. Its effects are shown in Figure 3.10. In the proactive mode, there are two options: one is to intervene immediately, the other is to wait to until the problem occurs. If the cost of obsolescence of a component is very low, it may be more useful to develop a strategy in the reactive mode. It should also be noted that the decision to resolve the problem in the reactive mode is taken after performing the necessary risk assessments. This decision, therefore, becomes a part of proactive OM. If the obsolescence of the component has a high impact on the costs, but the probability of becoming obsolete is low, proactive mitigation methods can be applied. A component is labelled as "critical" if the component has a high probability of becoming obsolete as well as its effects on costs are high. Then, proactive mitigation measures are applied (Rojo, 2011). Figure 3.10 shows the relationship between the component's probability of obsolescence and its effect on costs.

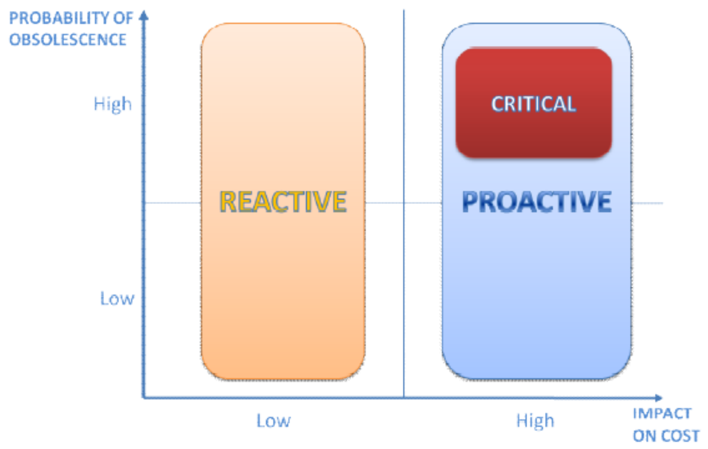


*Figure 3.10* Evolution of the Level of Obsolescence Based on the Management Approach (Rojo, 2011)

When the level of obsolescence is determined, and the decision on whether to apply proactive or reactive OM strategies is made, then mitigation strategies are implemented. The next section discusses such obsolescence mitigation strategies.

### 3.7.1 Obsolescence Mitigation Strategies

Experts in the British defense sector agree that there is a distinction between “mitigation strategies” and “resolution approaches”. Mitigation strategies are actions which are applied in order to reduce obsolescence risk and potential impacts on systems, whereas, resolution approaches are actions which are used once an obsolescence problem arises and needs to be dealt with (Rojo, 2012). Usually by combining multiple mitigation strategies, a strategy for OM can be formed to reduce the risk of obsolescence. In three main process of a company related to OM, which are supply chain management, design, and planning, mitigation strategy actions can be applied in order to reduce the risks of obsolescence. The following sections explain the mitigation strategies shown in Figure 3.11.

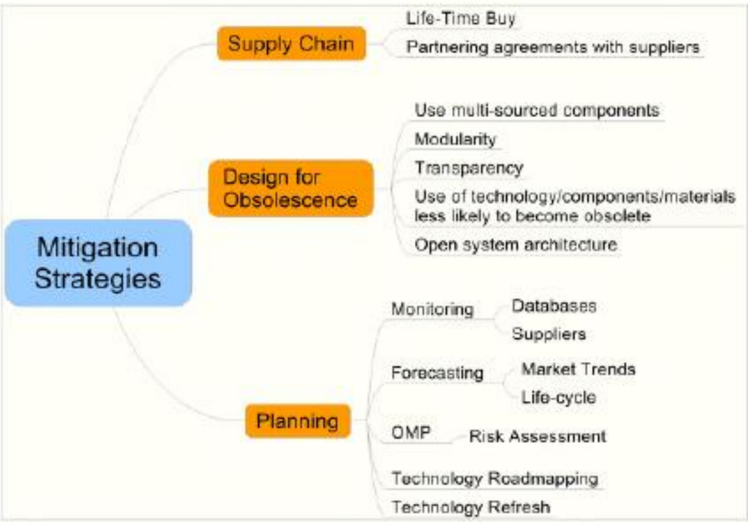


*Figure 3.11* Obsolescence Mitigation Strategies (Rojo, 2011; Rojo 2012)

#### 3.7.1.1 Mitigation Strategies for the Supply Chain

Life-time Buy (Life of Type) and partnering agreements with suppliers are two choices in a supply chain mitigation strategy (Rojo, 2011). Such strategies must not be limited to the mitigation for the supply chain, but they must take into account production planning, manufacturing, and maintenance and repair services related to after-sales services.

1. Life-time Buy (Life of Type):

The Life-time Buy (LFTB) (also known as Life-of-Type) mitigation strategy is defined as buying and storing sufficient quantities of components to fulfill a system's forecasted manufacturing and sustainment lifetime requirements (Singh et al., 2002; Feng et al., 2007; Rojo, 2011; Sandborn, 2013). However, it can also be put forward that it is also related with the supply chain plus production planning strategies as well as manufacturing and services. Determining the number of components to purchase required for LFTB is a crucial activity for optimization to minimize lifecycle costs. The critical cost factors include procurement, inventory, disposal, and penalty costs (Feng et al., 2007; Rojo 2011; Sandborn 2013). The critical cost factors are presented in Figure 3.12.

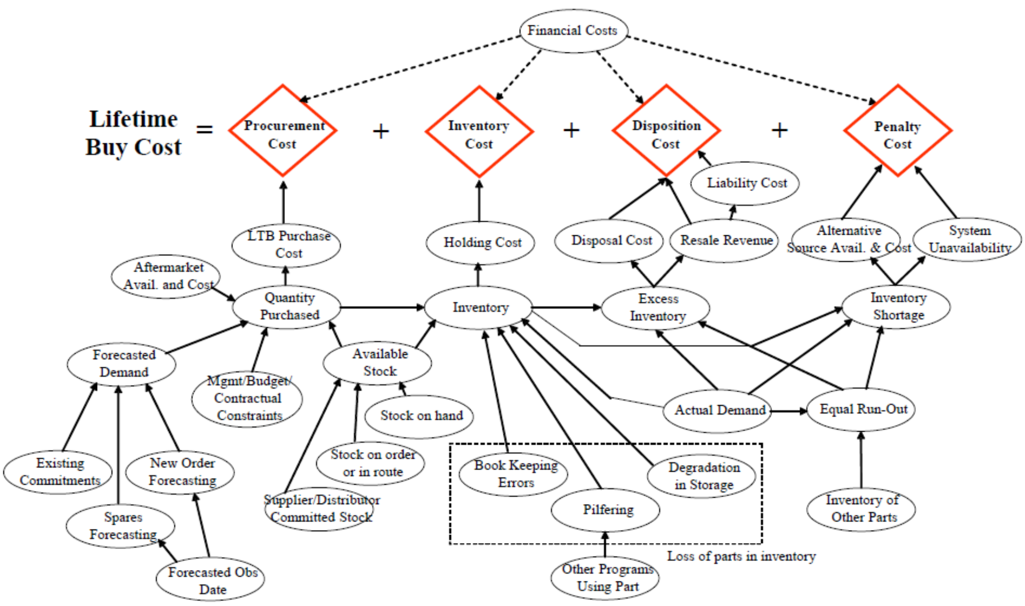


*Figure 3.12* Life-time Buy Costs (Sandborn, 2013)

With PDN, PCN, and LTB notifications, semiconductor manufacturers generally warn their customers and distributors with a notification about 6 to 12 months before a component is about to be discontinued. These notifications are the opportunities for customers or distributors to place final orders for components through a “Life-time Buy (LFTB)” (Feng et al., 2007; Sandborn, 2013). For the final order, users of the component must determine the quantities needed to fulfill the manufacturing and sustainment requirements of the system until the end of the project’s life. Procuring sufficient numbers of components is called a Bridge-Buy (LTB) until the system is at a point of design refresh in the future. In almost every obsolescence management plan, there are LTBs which play a critical role no matter which reactive, proactive, or strategic OM level is being used (Sandborn, 2013). To manage the risk of obsolescence in certain expensive components, management should decide to invest in the Last-Time Buys according to statistical data obtained from design manufacturing and requirements for the future. The decision can reach millions of dollars, affecting budget allocation.

One of the most critical advantages of LFTB is being always ready to use a component in the system, and the other benefit is to avoid requalification testing (Rojo, 2011). Nevertheless, there can be certain disadvantages in practice (Sandborn, 2013). Such drawbacks are defined by Rojo (2011):

a) Inventory costs will increase, due to the purchase of these components in advance, well before they are needed (Feng et al., 2007; Rojo, 2011).
b) Forecasting the demand on the component and correctly identifying the Life-time Buy amount is challenging (Feng. et al. 2007; Rojo, 2011). Thus, there can be excess inventory or shortage problems (Rojo, 2011).

c) An assumption of LFTB is that the design of the system will be stable (Feng et al., 2007; Rojo, 2011). Yet, the stock that comes through Life-time Buy may become obsolete because of unscheduled or unplanned design refresh, and thus may not be needed (Rojo, 2011). This issue can create millions of dollars of damage, and therefore risk management must be carried out carefully based on forecasts.

d) Buyers have minimal negotiation options against suppliers because of dependency on a specific supplier (Rojo, 2011). Namely, defense companies do not have much power while negotiating with the suppliers of electronic components.

The following section discusses partnering agreements with suppliers, in order to minimize the drawbacks of OM.

2. Partnering Agreements with Suppliers:

COTS components are heavily used in the supply chain of defense and aerospace industries, and for this reason, companies have less power of control on COTS components (Sandborn, 2007a; Feng et al., 2007; Rojo, 2011; Sandborn, 2013). Thus, in order to ensure continuous support from the supplier side and provision of critical components, it is strongly recommended to engage in partnering agreements with suppliers (Rojo, 2011).

The importance of these agreements is also recognized by the UK Ministry of Defense (MoD) and the Defense Equipment & Support (DE&S) (DE&S supports the UK's defense forces for current and future operations). In accordance with the Defense Industry Strategy, DE&S and its obsolescence management team engage in partnership agreements and private finance initiatives to apply effective solutions, and manage industry collaborations (Rojo, 2011).

#### 3.7.1.2 Mitigation Strategies for the Design Phase

It is inevitable that technology obsolescence will affect military systems during their long lifetime (Rojo, 2011; Sandborn, 2007a). This stresses the importance of the design phase where components are determined, and the design is fixed for long periods of time (Meyer et al., 2004; Feldman and Sandborn 2007; Rojo, 2011). Overcoming obsolescence problems, which may occur at the component or Line Replaceable Unit (LRU) level, will be easier through the use of open systems architecture, modularity, and increase of standardization during the design phase (Rojo, 2011).

Condra (1999) and Rojo (2011) assert that the functionality of a military aircraft and the effect on the lifecycle cost of the electronic component's obsolescence may dramatically be decreased by implementing the following:

1- The methods used to select components to assure cost-effectiveness, safety, and reliability should be well managed (Rojo, 2011).
2- New methods can be created for using components produced for other industries (incorporating COTS) (Rojo, 2011).

Hence, the electronic components manufactured for the commercial market should be used and taken advantage of by the defense industry, according to Condra (1999) and Rojo (2011). Nevertheless, the fact that COTS have a shorter lifecycle, using them can have both favorable and unfavorable consequences. It may increase the rate of obsolescence problems in the system, or aggravate the problem as discussed in Section 2.5 (Rojo, 2011).

The use of multi-sourced components is important when designing for obsolescence. The total number of manufacturers and suppliers which are producing a specific component (incorporating a specific technology) should be determined at the design stage before any of the components are included in the BOMs. In order to minimize the number of critical components, it is important to be able to ensure that they can be supplied by multiple manufacturers (Rojo, 2011). Thus, a company can add alternative choices of components on BOMs at the design phase. It is especially important to define alternatives for transistors, which quickly become obsolete in the market. Similarly, when using LEDs in designs, alternatives must also be identified in the BOMs, and "Partnering agreements with LED suppliers" are essential to consider when creating mitigation strategies for LED components.

**3.7.1.3 Mitigation Strategies for Planning**

Planning is an effective way of mitigating obsolescence, by improving the Obsolescence Management Plan (OMP) and enabling efficient use of obsolescence monitoring tools along with the technology roadmaps (Rojo, 2011). Monitoring can provide important information for planning and proactive obsolescence management. Monitoring BOMs is carried out by commercial tools which have large component databases. These commercial tools are matched with the databases of companies containing BOMs. They provide the current status for each component where obsolescence data can be known or estimated in years to EOL in the market. The estimation via tools is based on an algorithm. This algorithm is based upon several factors such as type of component, technology maturity, and market trends. Moreover, BOM monitoring tools may provide information about FFF replacement alternatives to replace the obsolete, LTB, and NRND components (Rojo, 2011).

Forecasting obsolescence for planning must take into account market trends and the life cycle of products. Factors to be considered are (Rojo, 2011):

1. Component type (e.g., electronic or mechanical)
2. The complexity of the component (low complexity versus high complexity, or IC versus Non-IC such as resistors versus microprocessors)
3. Technology built in the component
4. Level of maturity of the technology built in the component
5. Number of suppliers of the component
6. Market trends
7. Changes in laws and regulations, due to electronic market developments

According to the above factors, companies use obsolescence management data of electronic components to classify their component library. Moreover, they use commercial obsolescence monitoring tools such as Q-Star, IHS, TACTRAC, and Silicon Expert.

An OMP embodies methods to deal with obsolescence issues in a proactive manner. The OMP includes the mitigation and resolution obsolescence approaches proactively across the lifecycle of the project (DoD, 2005; Rojo, 2011). The OMP document considers obsolescence risks, and the most suitable obsolescence strategy is provided to the customer and the prime contractor (Rojo, 2011).

Technology road mapping enables the selection of technologies with a long lifespan. This method facilitates the identification and selection of various technology alternatives (Bray and Garcia, 1997; Rojo, 2011). The main advantage is to allow better technology investments to be made and to identify gaps in technology (Bray and Garcia, 1997; Rojo, 2011). According to Rojo's study in 2011, the use of technology road mapping is important for planning technology refreshes. Renewing technology may help a system, and may be required within the 'in-service' phase of the CADMID cycle, for avoiding and resolving obsolescence issues (Rojo, 2011).

### 3.7.2 Obsolescence Resolution Approaches

Obsolescence resolution approaches are divided into four categories: same components, FFF replacement, emulation, and redesign (Figure 3.13). After electronic components become obsolete, in order to deal with the obsolescence problem in hand, resolution approaches must be applied as soon as possible. With the resolution approach chosen, it must be guaranteed that no pre-existing capabilities are overlooked. The suitability of the resolution approach should be evaluated case by case (Rojo, 2011).

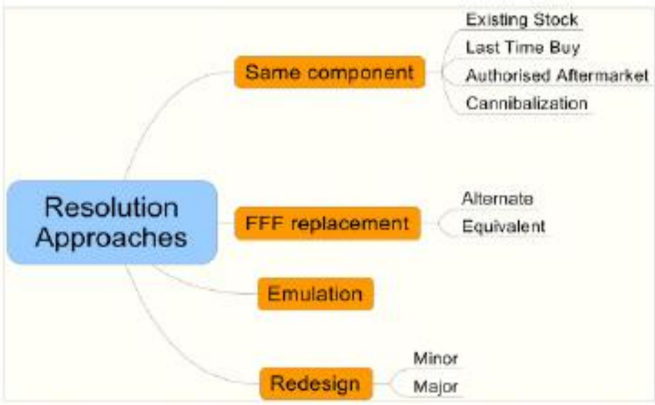


*Figure 3.13* Obsolescence Resolution Approaches (Rojo, 2011; Rojo, 2012)

#### 3.7.2.1 Same Component

As a resolution approach, the term “same component” defines the replacement of obsolete components with the same component. This can be achieved from existing stock, as LTB, from authorized aftermarket sources, and through cannibalization.

1. Existing Stock:

These are the obsolete parts available in the supply chain that can be used. The existing stock resolution approach is a cheap solution; however, it is short term. Therefore, after applying this solution, there will be a need to search for a longer-term solution. (Rojo, 2011).

2. Last-time Buy:

After a Product Discontinuance Notification (PDN), Product Change Notification (PCN), or EOL notification from the component’s supplier, Last-time Buy (Bridge Buy) means purchasing and storing the component in sufficient quantities. Last-time Buy (LTB) components support a product or system during its life cycle or until the next planned technology refresh (Meyer et al., 2004; Rojo, 2011). Last-time Buy (LTB) should not be confused with Life-time Buy (LFTB). While LTB is triggered by a supplier’s notification reporting a future end of manufacturing, LFTB is a risk mitigation option, which is triggered by the users’ risk analysis of the component as described above. The most important benefit of Last-time Buy is that it saves time by resolving OM problems, until a redesign becomes necessary. Last-time Buy is frequently used, and it is an effective resolution approach. However, it is a short-term solution until deciding on a permanent solution such as redesign (Rojo, 2011).

3. Authorized Aftermarket Sources:

When the original manufacturer of the electronic component discontinues production, the production of the obsolete component can be authorized by the original manufacturer to third parties. The procurement of this obsolete component from these third-party manufacturers is called Authorized Aftermarket Sources (Rojo, 2011). Authorized Aftermarket Sources is an advantageous resolution approach, since, it is relatively cheap compared to other solutions (Rojo, 2011) such as buying obsolete components directly from the market. On the other hand, quality considerations must be at the forefront when purchasing from these sources.

4. Cannibalization (Reclamation):

The cannibalization resolution approach is the use of recoverable maintenance parts from unserviceable systems, which is also known as using salvaged serviceable parts. (Meyer et al., 2004; Rojo, 2011). This resolution approach is functional during the last stage of the in-service phase in sustainment-dominated systems. However, the danger is that the used part might be just as prone to obsolescence as the one it is replacing (Rojo, 2011).

There are two other approaches: purchasing parts from the grey market, or from secondary markets. The grey market is the purchase of goods from unauthorized, informal, unofficial or unwanted distribution channels of new goods by the original manufacturer. There are several companies that purchase grey market goods as an alternative to redesign. Nevertheless, sources of grey market need to be investigated in terms of component's counterfeit risks which create high safety and reliability concerns. In addition, testing all electronic parts is not a feasible solution to counterfeit risk, thus, this approach is not recommended. It is also quite risky to buy a component from a secondary market such as eBay, since the risk of counterfeit is also high, as well as quality issues, as in grey market components. Therefore, this is also not recommended as a resolution approach (Rojo, 2011).

#### 3.7.2.2 Form Fit Function (FFF) Replacement

There are two categories in form fit function replacement: alternate component and equivalent component.

1. Alternate:

The definition of an alternate component is “a part available that is equal to or better than that specified” (Rojo, 2011). One of the most important advantages of this approach is that it is cheap (as there is no need for re-qualification tests) and is often used as a long-term alternative. On the other hand, finding a replacement with the same form fit function is challenging (Rojo, 2011), especially for high complexity parts.

2. Equivalent:

The definition of an equivalent component is “a part available whose performance may be less than that specified for one or more reasons (e.g., quality or reliability level, tolerance, parametric, temperature range)” (Rojo, 2011). The equivalent resolution approach is also known as “substitute” in the US DoD (ARINC, 1999; Rojo, 2011). A substitute component might work with full performance in terms of form, fit, and function. However, the component’s substitute needs to be tested in order to ensure that the COTS equivalent meets the characteristics and specifications required by the company (Rojo, 2011).

#### 3.7.2.3 Emulation

This approach can be used for electronic components such as Field Programmable Gate Arrays which can be programmed with emulators (FPGAs). Emulation is the development of the same form of the obsolete component with the latest technology. An emulator is an interface software that makes it possible to "continuing the use of legacy software in new hardware where otherwise the legacy software would not work properly" (Rojo, 2011). It is a short-term solution by using the built-in adapter with COTS components (Rojo, 2011).

#### 3.7.2.4 Redesign

The redesign alternative is based on upgrading the system changing the obsolete components with new ones, and the goal of the redesign alternative is improving systems or card's performance, maintainability, and reliability, as well as enabling the use of new components. This is the most expensive solution due to requalification/re-certification requirements. Thus, this long-term solution should be used as a last resort. It should also be used when functionality upgrades (technology insertion) are required (Rojo, 2011). Replacing the obsolete part with the redesign alternative entails long time and high cost when compared with other resolution approaches.

Following the discussion of mitigation and resolution approaches, the relationship between obsolescence and inventory is presented in the next section.

### 3.8 Obsolescence and Inventory

Analyzing and evaluating obsolete components in inventory is based on data of the electronic components from the company's processes and MRP data of the company. In order to decide which OM strategy should be implemented, inventory control plays a crucial role in a company's financial situation. Anything related to obsolescence that can affect inventory must be carefully monitored. The probability of component obsolescence and its impact on cost is not only related to determine the estimated obsolescence of the component, but also managing inventory in a more controlled manner. It leads to the determination of which OM strategy to apply. Inventory control in relation to obsolescence is important. However, Song & Zipkin (1996) put forward that: "Traditional inventory-control methods make no allowance for possible obsolescence." It is true that traditional methods of taking inventory will have to adapt to the difficulties brought by component obsolescence. In order to perform efficient inventory control, the obsolescence dates of components need to be established. Additionally, obsolescence managers must consider not only the date of estimated obsolescence of the component, but also the impact of environmental regulations, as well as the financial risks, manufacturing schedule, and other external constraints that can affect the system, resulting in inevitable obsolescence (Herald et al. 2009).

An inventory policy is the Consignment Stock (CS) inventory policy that companies adopt to deal with new manufacturing and supply chain management challenges. CS policy addresses cooperation between the buyer and its supplier. The CS policy brings a uniform exchange of information and consistent sharing of risks between the parties. Product obsolescence impact is assessed carefully in terms of supply chain costs. CS means the supplier continues to keep inventory for the buyer, even though it no longer keeps inventory for general sales purposes. The buyer has the advantage of sustaining the availability of the component, where the vendor undertakes the replenishment and inventory management responsibility, making it possible to reduce total joint costs and stock-out risks based on agreements between the two parties (Catena et al., 2014).

The CS policy is not applicable to all components in inventory, and can be applied to high complexity components because of their obsolescence risks and impact on cost. It is suitable for critical components, and can be considered for partnering agreements with suppliers as a mitigation strategy as described in Section 3.7.1.1.

When identifying resolution approach options for obsolete components, excess inventory must also be assessed. Furthermore, when redesign is the option to mitigate obsolescence, in cases where supply related options are not applicable, inventory data is required when changing the obsolete component. Moreover, standardization of the Preferred Part List (PPL), which provides a better component selection for designers and reduces inventory, is based on careful inventory management (Meyer et al., 2004).

As a supply chain mitigation strategy, Life-time Buy (discussed in 3.7.2.1) affects the company's inventory, since it leads to the advanced storage of obsolete parts. In order to decide which obsolescence strategy is implemented, obsolescence costing is significant for defense systems.

## 3.9 Obsolescence Costing for Contracts of Defense Systems

The cost of resolving obsolescence issues are not included in contracts to support a sustainment-dominated system. The prime contractor is obliged to resolve obsolescence issues and the customer meets the cost of these problems. However, the current trend in contracting for the support of a sustainment-dominated system is moving towards contracting for availability. In theory, availability-based contracts shift the risk from the customer to the prime contractor. However, the risk of obsolescence is in effect shared between the customer and prime contractor in line with the clauses in the contract. As a result, in this new contract type, both parties need to accurately estimate the WLC of obsolescence, since contracts cover long periods, and the prime contractor has a low-profit margin and high risk (Rojo, 2011), and risk factors and cost drivers (cost metrics) need to be carefully identified.

A cost model is needed to estimate the total cost that will be incurred while mitigating and resolving obsolescence issues. This cost model should be able to estimate the cost of obsolescence with information from the BOM and the data of obsolescence predictions from the BOM monitoring tool. To estimate life-cycle costs of systems, there are many commercial tools such as True Planning (PRICE Systems, 2019) and SEER (Galorath, 2019), however, these tools are not capable of estimating obsolescence costs (Rojo, 2011).

The following chapter presents the detailed analysis of the current obsolescence management related processes within the company.

# CHAPTER 4

# ANALYSIS OF OBSOLESCENCE MANAGEMENT RELATED PROCESSES WITHIN THE COMPANY

This chapter presents the analysis of the current workflow among the four main obsolescence related processes, and the obsolescence issues encountered due to the lack of a formal OM process in the company. An obsolescence management problem recently encountered is also described in order to highlight the shortcomings in the workflow, and the impact of obsolescence.

## 4.1 Methodology

The methodology for deriving the above mentioned consists of structured systems analysis, document inspection, interviews, and observations. The results are presented in Figure 4.2 as workflows created by using the Microsoft Visio modelling notation.

Structured systems analysis starts with the determination of each obsolescence related process, the detailed examination of each of the steps of these processes, and the process owners. Then, the data inputs required to carry out each of the process steps and the information produced as outputs of these steps are established. Next, the time it takes to complete the process, its frequency, and volume (i.e. the number of times it is carried out) are examined. Finally the controls related to these processes are investigated, and missing controls are found.

Document inspection is carried out in order to understand the existing processes in the company. These documents consist of the company’s formal policies, regulations, directives and procedures.

These cover, among others, processes such as: procurement, resource management, configuration management, project monitoring and control, design verification, system development and safety, product life cycle management, proposal preparation, bidding and contract implementation. Project management principles, procedures for the creation of material documents in the ERP, and directives for the electronic components management plan are also among the documents reviewed.

In addition, procedures for establishing the quality assurance provisions for purchased parts, supplier quality performance grades; reliability prediction analysis, and electronic component selection; product maintenance principles and methods, as well as procedures for stocking spare parts; procedures for the preparation of documents related to hardware requirements, hardware tests, schematic design; change decisions in designs workflows, production follow-up, production planning, and material transfers to subcontractors have been examined.

Interviews have been conducted with: two experts, and an expert engineer from Integrated Logistics Support and Contract Management, four employees from Supply Chain (two experts, two expert engineers), 10 employees from R&D (8 senior hardware design engineers, two hardware design engineers), and two experts from Project Management. Interviews have also been conducted with PLM maintenance engineers.

Observations have been conducted to assess the company's response to notifications of obsolescence by suppliers, and this revealed that the transfer of obsolescence information from supply chain management to other processes is incomplete, or sometimes such information is not even shared. Similarly, the search mechanism for alternative electronic components has been observed.

## 4.2 Processes Related to Obsolescence Management

As stated in Chapter 2, there are four main processes related to obsolescence management. These are: project management, research and development (R&D), manufacturing and services, and supply chain management, as shown in Figure 4.1. The company's R&D process, as further explained in this chapter, forms the basis of product development, hence obsolescence management (OM) of electronic components during R&D is of crucial importance. The emphasis of R&D is due to the fact that obsolescence problems should be identified during the design phases of the R&D process so that obsolescence mitigation and resolution strategies can be developed proactively. Another reason is that owners of the other three main processes consult R&D process owners about the OM of electronic component issues, and hence, the outputs of this process form the inputs to the other three processes.

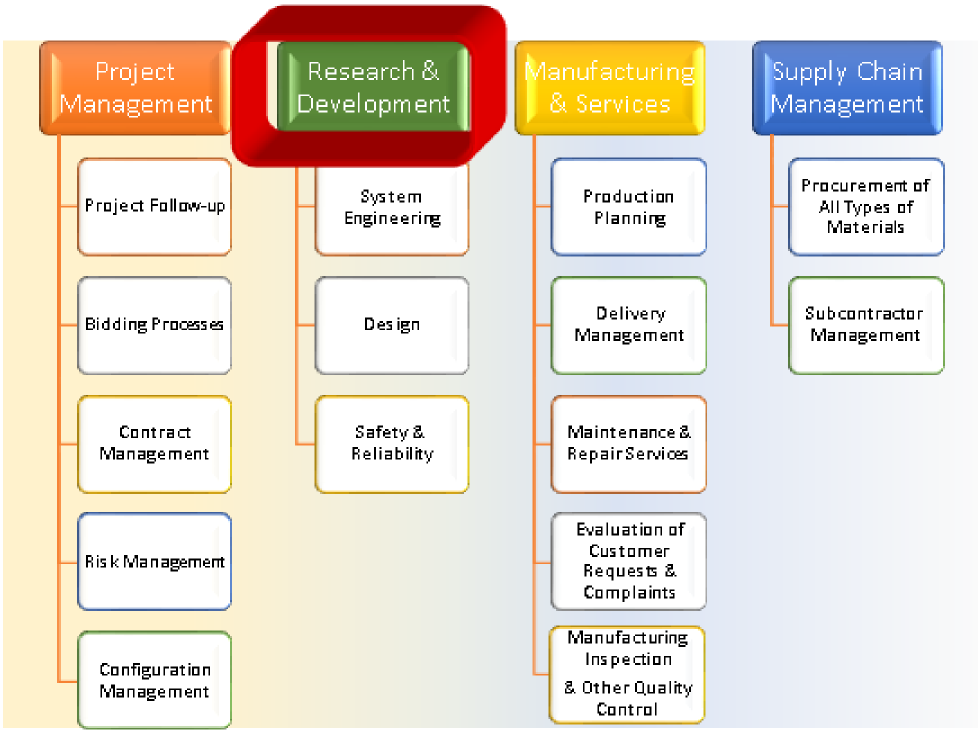


*Figure 4.1* The Company's Current Obsolescence Management Related Processes and Subprocesses

The following section analyzes the current workflow among these four main processes.

### 4.3 The Product Development Workflow

The company's products (also referred to as systems) are composed of assemblies and electronic cards. The electronic cards form the assemblies, whereas the assemblies form the systems. The smallest building blocks of electronic cards are electronic components.

The flow among the four main processes is shown in Figure 4.2. These main processes are represented on the x- coordinate of the figure, and are analyzed on the vertical decomposition (y- coordinate) consisting of three main design phases: concept design, pre-design, and critical design.

The design phases represented in the y-coordinate, serve to understand how electronic components advance across the four main processes within the existing workflows of the company.

The company's design phases shown in Figure 4.2 can be mapped to the CADMID phases described in Chapter 3. This is to facilitate the monitoring of electronic components throughout the workflow. Phases of CADMID are built atop the phases of the company, where the Concept (C) phase in CADMID is equivalent the company's "Concept Design Phase", the Assessment (A) phase in CADMID corresponds to the company's "Pre-Design Phase", and the Development (D) phase in CADMID is the company's "Critical Design Phase". The Manufacturing (M) phase in CADMID is the phase that begins after the "Critical Design Phase" where the production type of the electronic card is determined, and the card is transferred to the process of manufacturing and services. The in-service phase (I) in CADMID matches the in-field life of the system, followed by the Disposal (D) of the system.

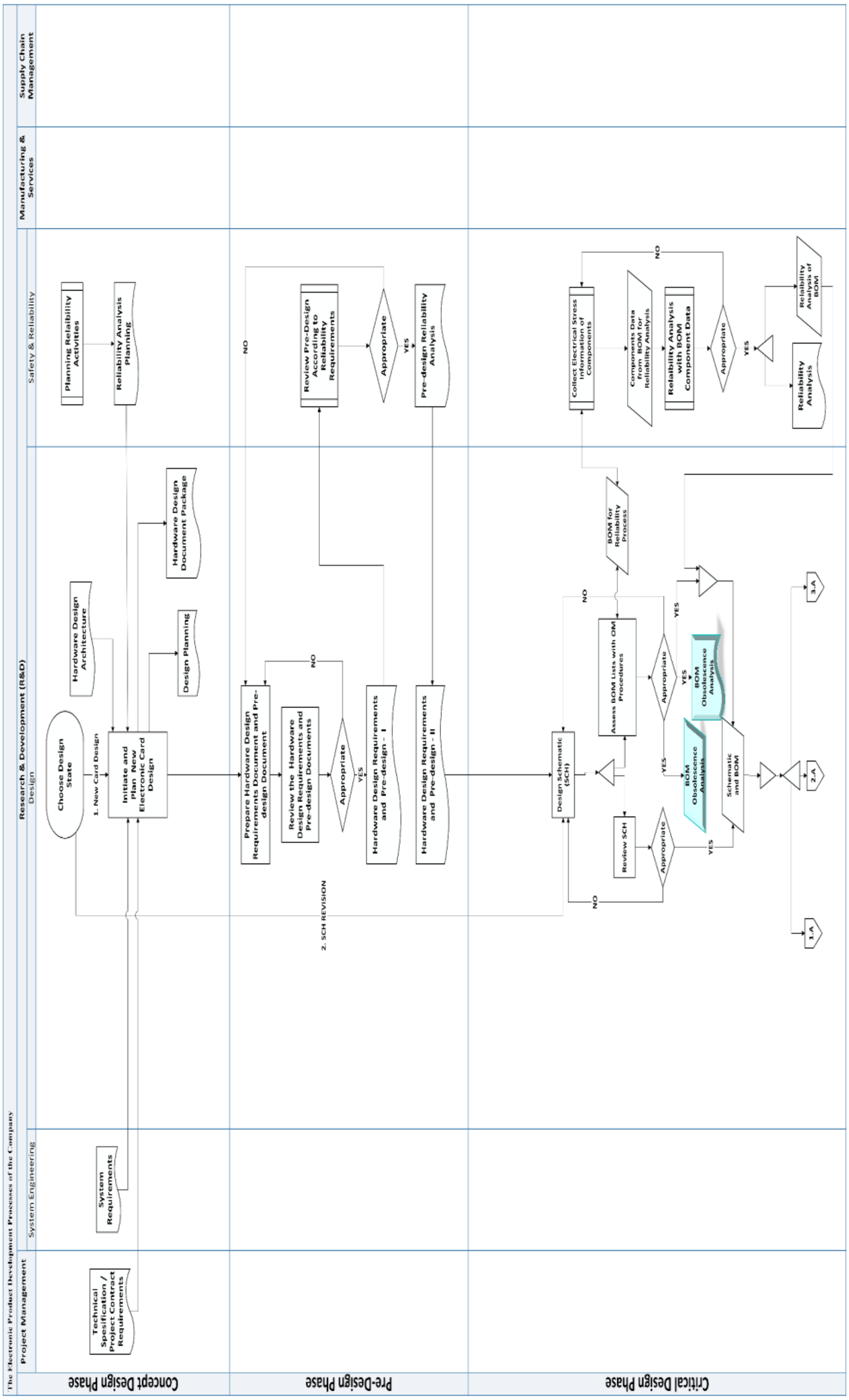


*Figure 4.2* Workflow among the Four Main Processes

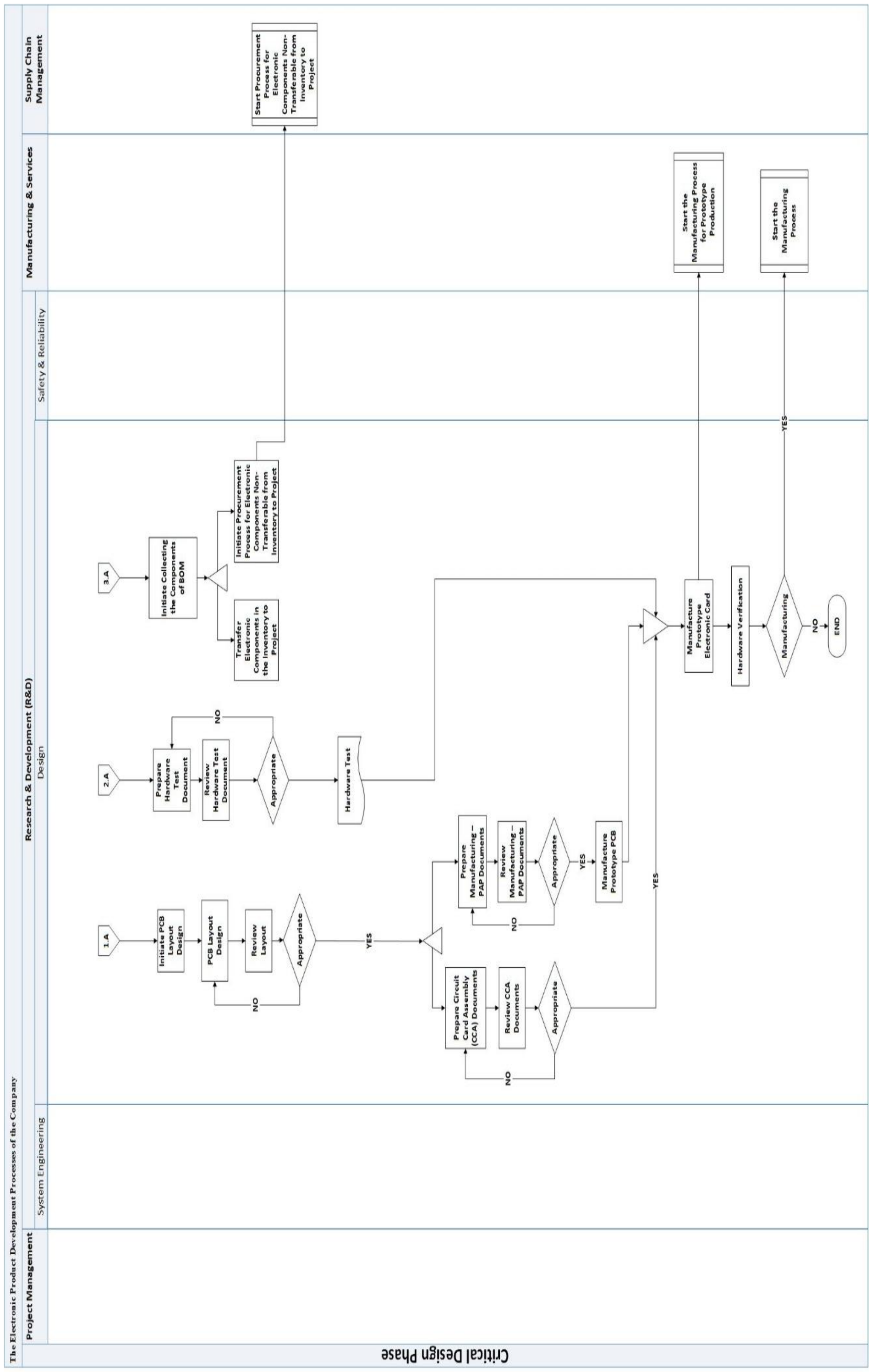


*Figure 4.2* Workflow among the Four Main Processes (cont’d)

The following sections describe in detail the product development workflows and documents related to OM, starting with the "Concept Design Phase".

### 4.3.1 The Concept Design Phase

In the concept design phase, the first step is "Choose a Design State" with respect to the design process of R&D. There are three design states: new electronic card design, schematic (SCH) revision with printed circuit board (PCB) revision, and SCH revision without PCB revision.

The first design state involves starting the design of a brand-new electronic card. The second design state is when an electronic component change is necessary on the schematic of the electronic card, and if it involves a change with a potential impact on the circuit paths and connections to other components on the SCH and PCB, it is referred to as the schematic revision state with PCB revision. The alternative component to replace the one that is obsolete, requires changes on the SCH, on the Circuit Card Assembly (CCA) document, and on the PCB. The PCB document contains information about PCB layers, electrical paths, PCB manufacture information, and size of components. For instance, when there is a change in the component dimensions during component replacement, this must be reflected in the PCB document. Further, due to the replacement of components, the CCA document must be updated as per the change in component information. This state begins with the process of "Design Schematic" if electronic component changes lead to the schematic changes on the electronic card.

The third design state, the SCH revision state without PCB revision, is initiated for electronic component changes without any modifications in PCB layouts. But as a component is replaced, information of the new component needs to be updated in the CCA and SCH documents. For example, when pin-to-pin compatible (form-fit-function) alternatives are utilized in the replacement, its dimensions will remain the same while changes will not be necessary on the PCB document.

During SCH revisions, it is of paramount importance to plan well for the electronic component changes and conduct a thorough research for their alternatives. In that way, consequent PCB revisions will be avoided during SCH revisions. It is therefore a must to appropriately manage obsolescence-related issues and component replacements.

The electronic components of electronic cards are included in the Bill of Materials (BOM) lists, and the BOM lists are cited as design documents of R&D process in the company's Circuit Card Assembly (CCA) documents. CCA Document-related process is initiated by the process of "Prepare Circuit Assembly Card (CCA) Documents". In CCA documents, information on alternative components (if any) are saved in an extra box under the location information for the electronic components. However, this is at the discretion of the designer. There is no set procedure for adding alternative component information in CCA documents.

Replacing the electronic component in the second and third design states is a significant factor in the calculations of the performance of electronic cards. For instance, if there are multiple occasions of obsolete component replacement on a card, it means that several workflows are restarted during card design and manufacture processes. In such cases, the number of revisions stemming from changes of electronic components on cards may occur more than once. Consequently, this acts as a significant but negative blow to the efforts on maintaining a reasonable total cost of design, resulting from heavily increased redesign costs. At the same time, the more revisions are made on the electronic card, the more time, financial resources, and labor will be expanded. Along the same line, had the company adopted an obsolescence management plan, such costs could have been avoided or at least reduced. Therefore, controlling and managing design revisions that may result from obsolescence is a factor that significantly affects electronic card design costs which are directly related to project performance.

In the concept design phase, the initiation of new electronic card design is triggered by the “Technical Specifications Document” or “Project Contract Requirements Document” within the framework of the project management process, as well as the “System Requirements Document” within the framework of system engineering subprocess of the R&D process. The “System Requirements Document” defines the system, assembly, and electronic card level properties. These are inputs to the “Initiate and Plan New Electronic Card Design” process of R&D. The other inputs to this process include the “Reliability Analysis Planning Document” stemming from the safety and reliability subprocess of R&D, and the “Hardware Design Architecture Document” created by hardware design architecture.

One of the primary activities in the concept design phase is the generation of the “Hardware Design Architecture Document”. The electronic components of the system are included in the functional blocks (also defined as modularity of design) of the “Hardware Design Architecture Document”. The critical components with high complexity (such as Field Programmable Gate Array components (FPGA)) are contained within the modular blocks and they are also included in the “Hardware Design Architecture Document”. Thus, the monitoring of an FPGA component until the end of the product lifecycle is crucial in order to minimize the abovementioned costs. Hence, future obsolescence risks must be considered, yet there is currently no such procedure.

The outputs of the concept design phase include the “Hardware Design Document Package” and “Design Planning Document”.

According to a project’s reliability requirements, the “Planning Reliability Activities” subprocess of R&D begins while the concept design phase continues. The output is the “Reliability Analysis Planning Document”, which is used in the “Initiate and Plan New Card Design” process, as an input.

### 4.3.2 The Pre-Design Phase

The pre-design phase consists of the preparation of the “Hardware Design Requirements and Pre-design Document – I”.

This document is an input to the safety and reliability subprocess of R&D, and is reviewed according to reliability analysis requirements in pre-design. If the electrical components meet the requirements in relation to electrical stress information of components for reliability analysis at the pre-design phase, the “Pre-design Reliability Analysis Document” is generated as an output.

If the electronic components do not meet the requirements, the process owners of the “Prepare Hardware Design Requirements Document and Pre-design Document” assess the electronic components within the reliability framework of the design. In such a case, the reliability analyses of electronic components that do not meet the requirements during the pre-design phase are not recorded in internal electronic component libraries, due to the fact that there is no such formal procedure.

If the review has an appropriate result, the “Hardware Design and Pre-design - II” is generated and the “Hardware Design Document Package” is updated, which is then transferred to the critical design phase.

### 4.3.3 The Critical Design Phase

After the completion of the pre-design phase, the critical design phase begins with the “Design Schematic” process. The schematic circuit design is done by using electronic card design tools (ECDTs). The electronic components of electronic cards are selected from electronic card design tool libraries (ECDTLs). The current obsolescence approach within the company consists of checking the obsolescence conditions of components in ECDTLs once every six months, which is questionable in terms of its frequency. Another problem is the lack of obsolescence checks of other electronic components, which are only registered in the ERP and not controlled at this stage. Only components in the ECDTLs are checked. Hence, OM issues arising during the six months between obsolescence checks cannot be reported to relevant process owners immediately after they occur due to the length of these periods. It should also be noted that designers are only informed about the obsolescence status of the components through ECDTL checks by designers, meaning other process owners are not informed of the issue.

Once the “Design Schematic” is complete, the result of this process is reviewed in terms of circuit properties. Simultaneously, BOM lists are checked for obsolescence of electronic components. If new components are to be added or removed, this decision is to be made at these stages. Checking obsolescence conditions from BOM lists does not suffice, which often gives rise to obsolete components being overlooked, since the OM checks on BOM lists are performed on a case by case basis when each card arrives. In other words, according to current procedures, obsolescence checks are performed for every new design; however, the company does not undertake the same efforts for systems in the field, or projects that were designed previously. This is why obsolescence issues can go unnoticed for electronic cards that have not been checked.

When obsolescence as well as the components' future obsolescence conditions are reported to designers, the Last Time Buy (LTB) or Not Recommended for New Designs (NRND) status of the components are recorded in the "BOM Obsolescence Analysis Document". The process is performed only for new designs by the Design Department without any contributions from system engineering, safety and reliability engineering, and manufacturing and services. Consequently, as all components in the electronic card are not evaluated for OM in line with inputs from these processes, it also becomes more difficult to create an obsolescence strategy for issues to be faced in the future.

In addition, a comparison of the components based on their years to end-of-life (EOL) properties is performed for the schematic design. But the information is only stored in the "BOM Obsolescence Analysis Document". For example, obsolescence risks can be high for a component in its maturity phase, which should be monitored, but are not. The cost analysis of electronic components and recording the components' prices under the umbrella of the design subprocess is also incorporated in this step. If there are expensive components, their alternatives should be looked into. But once again this is limited to discretion of the designer of the electronic card. Components selected in this stage are currently not subjected to a supervision jointly conducted with, for example, the supply chain management process.

The "Collect Electrical Stress Information of Components" starts in parallel to the process of "Assess BOM Lists with OM Procedures". Along with the electrical stress values (voltage, current, temperature) of components, the BOM data is sent to the subprocess of “Collect Electrical Stress Information of Components” for the purposes of reliability prediction analysis.

The “Components Data from BOM for Reliability Analysis” data is forwarded to the subprocess of “Reliability Analysis with BOM Component Data”, consequently the error status of components is examined within this process. In the case where appropriate results are achieved, the “Reliability Analysis” Document and “Reliability Analysis of BOM” data are produced as outputs. When the safety and reliability requirements are not met, the process owners of the “Collect Electrical Stress Information of Components” and “Design Schematic” processes re-assess the electronic components. The results of whether electronic components in the BOMs meet reliability requirements or not are kept in the subprocess of safety and reliability engineering and are not formally recorded. During these processes, if records were kept about the design histories of these components under preferred part list practices against components that do not conform to the reliability requirements, the company could indeed take advantage of an up-to-date record and know-how on preferred and non-preferred parts for its future designs.

Further, the “Reliability Analysis of BOM” data is merged together with the “BOM Obsolescence Analysis” document. The results produced by the “Review Schematic” process as well as the results of “BOM Obsolescence Analysis” are inputs to the schematic and BOM data file. Next, the “Reliability Analysis of BOM” data and “BOM Obsolescence Analysis” document are included as updates in the “Hardware Design Document Package”. However, data such as electrical stress values of components are not kept in a standardized preferred part list for the purpose of developing OM strategies against obsolescence risks. Thus monitoring them dynamically throughout product lifecycles is not possible.

After the generation of the “Schematic and BOM” data, the phases of the critical design workflow continue simultaneously in three different processes: “Initiate PCB Layout Design”, “Preparation of the Hardware Test Document”, and “Initiate Collecting the Components of BOM”. The process of “Assess BOM Lists with OM Procedures” must be completed before proceeding to the layout design of the card since placing components on the card and its PCB manufacture begin after the initiation of the “PCB Layout Design” process. If there is a change of component after assessing obsolescence conditions in BOM lists, possible component changes on the card become more difficult, leading to a waste of time and failure to achieve cost efficiency. If obsolescence issues are encountered after the PCB design, and obsolete components are replaced after PCB design and electrical paths are modified, this results in a waste of financial resources. Effectiveness in such cases can be achieved by checking against obsolescence during schematic design.

The first process among the three simultaneous processes is the “Initiate PCB Layout Design” process of the design subprocess. Following that, the process of “PCB Layout Design” starts. After the process of “PCB Layout Design”, the subsequent process is “Review Layout”. In the case that appropriate results are achieved in the process of “Review Layout”, two processes start simultaneously, which are “Prepare Circuit Card Assembly (CCA) Documents” and “Prepare Manufacturing (PPAP) Documents”.

After the component placement is complete in “Design Layout”, the review of the component placement step begins and is performed according to the review checklist. If the placement of components on the PCB is found to be inappropriate both electrically and mechanically, the process owner of the “PCB Layout Design” re-assesses the electronic card’s layout. In other words, the electrical paths on the card between components begins to be drawn. After the electrical paths on the card are complete and once the reviews are found to be appropriate, the “Prepare CCA Documents” and “Prepare Manufacturing PPAP Documents” processes required for electronic card production are initiated simultaneously. If the “Prepare CCA Documents” and “Prepare Manufacturing PPAP Documents” processes produce inappropriate results, the process owners of “Prepare CCA Documents” and “Prepare Manufacturing PPAP Documents” re-assess the electronic card’s CCA and PPAP documents. After completing the preparation and review of these documents, these outputs are included in the “Hardware Design Document Package” (i.e., the package is updated). It is rather important to define alternatives for almost all components in BOMs of designs within the CCA documents. However, no definitive rule is enforced on designers to do so. Likewise, it is essential to constantly monitor the components that pose a risk in terms of EOL in these documents which should contain OM-related clauses. The lack of the enforcement of such rules causes significant costs to the company.

Once the necessary parameters are determined, the electronic card PCB design tool is used for placing components on the card. For the mechanical examination of the PCB, the design is then transferred to the mechanical engineering workstations. For example, heights of each component on the card at system and assembly levels are evaluated. If there is a need for change, components can be modified. Therefore, at this stage, components such as connectors and Light Emitting Diodes (LEDs) may be subject to change due to the obsolescence of the electronic components, which can lead to electronic card revisions (depending on the design state, for example design states 1 and 2). These are re-assessed during the design subprocess. At this stage, replacing LEDs, connectors, and the likes will have an impact on the component connections and paths in close proximity, as well as the fact that it might create further problems such as the difficulty of finding FFF alternatives for delicate components like LEDs. Having to replace components on grounds of obsolescence at this stage of the design may lead to risks such as the need to redesign. This is the main reason why OM monitoring and checks need to be performed carefully when selecting such components during design.

The second of the three simultaneous processes is the process of “Prepare Hardware Test Document”. After this, the process of “Review Hardware Test Documents” begins. When appropriate results are obtained, a “Hardware Test Document” is generated as an output. This output is used for the hardware verification of the electronic card, since once the PCB is manufactured, it must be verified together with its electronic components. This document does not contain information on alternative components to be used in case of obsolescence or failure in the supply of components in the electronic card.

The third of the three simultaneous processes is the “Initiate Collecting the Components of BOM”. This process is divided into two separate processes: “Transfer Electronic Components in the Inventory to Designers” and “Initiate Procurement Process of the Non-Transferred Electronic Components from Inventory”. Electronic components in the BOM are collected in accordance with the number of components in the CCA document during the process of “Initiate Collecting the Components of BOM” of the design subprocess. During the process of “Transfer Electronic Components in the Inventory to Designers”, the components in the BOM are withdrawn from the company inventory based on the number of electronic cards being produced.

For components unavailable in inventory, the process of “Initiate Procurement Process of the Non-Transferred Electronic Components from Inventory” begins and the supply chain management process initiates the subprocess of “Start Procurement Workflow of the Non-Transferred Electronic Components from Inventory”. After the procurement subprocess is completed, all components in the card’s BOM list are brought together to manufacture a prototype of the electronic card. During the procurement subprocess of supply chain management, as per the specified and planned durations in the project, the subprocess owners of design are once again consulted on whether there are alternatives with shorter lead times in place of the components with longer lead times in the BOM. The problem and inefficiency here is the fact that a period of time that was once dedicated for the progression of the workflow has already elapsed in the project. It is hence an approach condemned to lead to delays to ask designers to re-designate an alternative component at this stage in the project. Instead of this, the exchange of information with supply chain management about these common components after specifying alternatives should be achieved early in the project lifecycle at the “ Design Schematic” stage. However, there is no such common platform in the company where designers and supply chain management staff can interact about alternatives to components. The coordination in this regard is currently achieved through e-mail.

According to the information gathered from the outputs of the previous design subprocesses, the “Hardware Verification” process of the design subprocess regarding the hardware and the electronic components according to the revision checklist are prepared. Verification data is collected from previous processes for the verification of electronic components. The “Hardware Verification” process is performed after the prototype electronic card is manufactured. Then, according to production type, the subprocess of “Start Manufacturing Process” of manufacturing and services process is initiated for the production of the verified design.

Once all requirements are met and the “Hardware Verification” process is complete and system engineering, design, safety and reliability, and manufacturing and services documents are approved, the prototype electronic card is manufactured. The number of electronic cards to be manufactured are determined by the production planning department, and since the number of electronic components is determined by the number of electronic cards, this phase bears vital importance for the determination of OM strategies in the future. Further, for components that can fall in to the LTB category in BOMs in the future, it is important to develop accurate and foresighted Life Time Buy (LFTB) strategies. All the four main processes must be involved in reaching a decision on this, as they will be expected to present and develop OM-related approaches with regard to their own fields of expertise. There are no such processes to support this in the company.

When the Production Planning Department decides that cards are to be produced by subcontractors, common OM strategies can be developed with subcontractors depending on the number of components in these electronic cards. The company does not implement a specific OMP with its electronic card subcontractors, which may lead to severe obsolescence problems in the future. If the company and its subcontractors agree upon an OM checklist and on an OMP, potential obsolescence risks can be avoided or minimized.

In the design subprocess, the necessary hardware and software for prototype card manufacturing are designed, and the necessary components are selected for the project. After that, electronic card tests are conducted. The “Design Planning” and “Hardware Design Document Package” documents contain all of these plans from the beginning of the concept design phase to the end of the critical design phase. As a matter of fact, on grounds that the “Hardware Design Document Package” holds all hardware-related electronic component issues right from the beginning, it can be the foundation of the OM plan to be established within the company in the future.

Furthermore, the design subprocess utilizes a BOM obsolescence management tool to monitor the obsolescence of electronic components. During the "Assess BOM Lists with OM Procedures" process, the BOM obsolescence management tool helps to monitor BOM lists proactively. Also, the Product Lifecycle Management (PLM) tool is used by design engineers for managing the design subprocess. Yet the project management, supply chain management, and manufacturing and services processes do not utilize this tool. In fact, the company's PLM tool can be used to manage the information flow between these processes and enable various process owners to be involved in compliance with their levels of authorization. However, this is process integration through PLM is not done in the company.

The following section illustrates the OM problem of the company through an example.

## 4.4 Example of an Obsolescence Management Problem in the Company

A year ago, a Product Discontinuance Notification (PDN) from the Original Component Manufacturer (OCM) about the obsolescence of a flash memory component, which is a COTS component, was received as an alert by the Procurement Department (the supply chain management process). However, this crucial information was not delivered to designers of the projects involving this component. In other words, PDN information was not available to the project management process, R&D process, manufacturing and services process with respect to electronic cards, assemblies, and systems where the flash memory was used. Projects were underway without the necessary measure being taken. As there was no OM process to deal with this issue, nor a way to implement mitigation and resolution OM strategies, the situation went unnoticed by most of the related parties.

Thus, the necessary precautions regarding this flash memory component (for instance, the option of LTB) were not put into action for systems, assemblies, and cards produced or to be produced, that were using this component. It was discovered that necessary production planning activities were not performed adequately. No action was taken to develop an OM strategy by identifying the electronic cards, assemblies, and systems that employed the obsolete component in question. Particularly, since the LTB notification was not delivered by supply chain management to production planning, no act of LTB was considered by production planning.

The obsolescence problem was noticed by total coincidence by the system engineering staff while working on a project. Then, the issue of the flash memory component's obsolescence was forwarded by system engineering to the designer using the component in an electronic card, stating that it would be not possible to immediately supply the component for the system because of its obsolete status in the market. The system engineer began searching for an alternative component to ensure the supply of the obsolete component in sufficient quantities, reporting this only to the designer of the card in the system via e-mail.

While a search for the obsolete flash memory component in the market was conducted, the design engineers identified stockists that still stocked the obsolete component at much higher prices. At this point, there were two options: the first was to supply the obsolete flash memory from stockists in the market, the second was to find alternative components to replace the obsolete one, both of which meant high cost and delay for the projects' lifecycle. The quantities available from stockists were inadequate for the systems in which they were being used.

Having received a notification about the problem from the system engineering staff, the designer in attendance of the matter informed other designers who used the COTS flash memory component in their designs. Following this, a team from the design subprocess prepared a list containing the quantities of various cards, assemblies, and systems that used the obsolete flash memory. The list was obtained from the ERP system's library. The total number of flash memory components used was determined in this list. The list was first shared with the Departments of Production Planning and Supply Chain Management. It was also shared with the Department of Software due to the flash memory's software revision related to the obsolescence issue. It was further announced to designers using the COTS flash memory component in their projects via e-mail that approximately 80 electronic cards were using this component.

Next, the design team took the initiative of alerting the departments of the four main processes, and project managers who use the COTS flash memory component through an e-mail containing the advisory information described below. The purpose of this e-mail was to initiate the development of a reactive obsolescence mitigation strategy and resolution approaches to the problem.

- According to the e-mail, in order to resolve the obsolescence problem, the type of revision on the cards must first be established. In addition, the problem should be discussed among members of the design and production planning subprocesses.

- Necessary obsolescence management approaches should be discussed with subcontractors producing cards containing this component.

- Alternative components in all categories, including the FFFs, should be identified for electronic cards using the abovementioned flash memory. Their designs should be examined, and decisions on which type of revision should be applied to the cards should be determined. Schematic revision, PCB revision, or CCA revision should be applied according to the conditions of the alternative components found.

- Because of the category and high level of complexity of the flash memory component, the alternatives should be evaluated from both hardware and software aspects. The electronic cards, assemblies, and systems using the alternative flash memory component should be re-evaluated by software teams if software changes are also required.

- Due to the software and hardware changes caused by the replacement of the flash memory component, necessary hardware and software tests should be carried out on the alternative component. The tests are to be executed through the processes of R&D as well as manufacturing and services.

- The Production Planning Department should determine the future needs of the obsolete component through the MRP system. In the production planning subprocess, the future requirements of systems using this flash memory component, in terms of quantity, delivery date should be determined for each project and customer. In line with all the product contracts entered with customers on this component, and in compliance with the warranty clauses in these contracts, new strategies should be developed by specifying all actions to be taken within the framework of these clauses.

- The quantities of the obsolete flash memory component used in electronic cards should be obtained from the production planning subprocess; likewise, the available quantities of the obsolete component to be procured from the market should be obtained from the supply chain management process based on information from the stockists who still sell them. In other words, for electronic cards that cannot be revised, the obsolete component should be purchased from all stockists in the market, to be kept in company inventories. Considering the number of cards using this component (80 in total), especially the ones with multiple units of the component, a decision to revise cards would result in tremendous costs. Further, it would not be a feasible solution if implemented for all the systems in question. Since there is already an insufficient quantity of the component in the market, and as it is also commonly used for consumer products such as medical products, the component should be procured from the stockists in final possession of the component by the supply chain management process.

- The contracts covering the systems in which the obsolete electronic component is used, specifically the warranty clauses of these contracts, must be re-evaluated under the supervision and guidance of the contract management process.

Despite the measures recommended through e-mail described above, this obsolescence problem remained unresolved for approximately a year. This demonstrates the gravity of the issue. A decision as to which electronic cards among the set of 80 would be subject to which OM strategy could not be made. The determination of which electronic cards would be allowed to continue to contain the obsolete component could not be made. Aside from the costs incurred because of this problem, the more critical aspect is the fact that the obsolescence problem was not eliminated even after a year.

This example led to delays and high costs for the projects due to the lack of an independent OM process. One of the most prominent reasons for this problem is that electronic components used in product designs are not monitored through an internal PPL database within the company. Also, the electronic components of products at the levels of systems, assemblies, and cards should continuously be tracked within for obsolescence management. However, the company does not currently implement an independent obsolescence management process at any level other than under the design subprocess.

As can be seen, an OM capability joining the four main processes must be developed to foresee potential obsolescence threats during project development and manufacture. Moreover, the company also requires an OM capability for in-field systems and warranties in order to mitigate the risks and costs arising from such situations. This example shows the reactive approach of the company, and the damage caused by the lack of a formal OM.

Chapter 5 proposes an OM framework for the mitigation and resolution of such obsolescence issues in the company.

# CHAPTER 5

# FRAMEWORK FOR OBSOLESCENCE MANAGEMENT

In order to alleviate the obsolescence management problems in the company, a framework consisting of four main elements is proposed. These are:

1. The extension of the scope of Product Lifecycle Management (PLM) in the company,
2. The establishment of the company's Preferred Part List (CPPL) and standardization of the electronic component libraries,
3. The institution of Complex Event Processing (CEP) to administer obsolescence,
4. The "Shell Structure" connecting the company's existing obsolescence related processes with the new obsolescence management process recommended for the company, thus establishing a common platform for the flow of obsolescence information.

Each of these elements are described in detail in the following sections.

## 5.1 Extension of the Scope of Product Lifecycle Management

The company has a Product Lifecycle Management (PLM) system, where design subprocess documents are saved and shared for some electronic card designs and products which use these electronic cards. Currently, not all projects are registered in the PLM system; therefore, not all electronic cards are found in the PLM system, and consequently not all electronic components are included. Hence, the company must transfer all of its main processes to the PLM environment.

This will enable to see which phase the products containing these components are in, as well as to keep track of the projects throughout their lifecycle. The new OM process (Section 5.4) proposed for the company must also be included the PLM environment. Thus, the company can keep track of OM issues throughout the lifecycle phases of its products.

Furthermore, the design subprocess uses a BOM obsolescence management tool to monitor the obsolescence of electronic components (as described in Chapter 4). The company requires a fresh perspective by combining this BOM external obsolescence management tool and PLM, feeding the latter with a continuous flow of information coming from the former. As described in Chapter 4, during the "Assess BOM Lists with OM Procedures" process, the BOM obsolescence management tool helps to monitor BOM lists proactively. The Product Lifecycle Management (PLM) tool is used to manage the design subprocesses. Yet the project management, supply chain management, and manufacturing and services processes do not utilize either the PLM or the BOM obsolescence management tool. When all processes migrate to the PLM, the workflow can easily be followed by process owners.

The importance of PLM is that it enables control of all the processes, managing the flow of information during the phases of project lifecycles. Along with this, depending on their levels of authorization, process owners from different departments have the ability to follow OM related issues. Currently, the company does not use its PLM platform to integrate OM related processes. The proposed extension of PLM, enables the company to track electronic components as products' parts in the processes, as they move from one phase the product lifecycle to another.

## 5.2 Establishment of the Company's Preferred Part List and Standardization of the Electronic Components Libraries

Currently, electronic components are recorded in the ERP, ECDTLs, PLM, and registered in the BOM obsolescence management tool's external database. As such, information pertaining to a single component is fragmented, and tracking is difficult, requiring the use of these different tools separately. Moreover, this situation gives rise to redundancies, duplications, and errors. It is therefore necessary to integrate this fragmented component information.

In order to create the company's PPL (CPPL) as an internal database and tackle obsolescence issues, the first step for the standardization of electronic component libraries is the classification and collection of electronic components data from the internal systems (ERP, ECDTLs, PLM) of the company and the external BOM management tool, as well as from the external electronic component market (suppliers, distributors). It is essential that process owners access this CPPL database.

Monitoring the frequency of usage of components can contribute to the establishment of the CPPL. When alternatives of components exist, their frequency of usage will show that a component is more preferred by designers, which will make this component a "preferred part" to be included in the CPPL.

Efficient management of electronic component data produced by the company's processes is a critical success factor for the company. Electronic component data are crucial inputs to the OM process. From the beginning of the concept design phase to the manufacture of a product, the usage frequency of the component needs to be managed with an OM process for each system within the company. In that way, the CPPL database is updated continuously. In addition, the usage frequency of categorized sets of electronic components in projects based on their obsolescence status can guide future decisions. These decisions may involve whether a given component category will still be procured after a number of years, whether it is necessary to upgrade to a better technology, or whether a design refresh plan should be undertaken. The usage frequency can further play a significant role in bidding for projects as explained in Chapters 2 and 4, and prevent future contract cost overruns. The results of the usage frequency of components with regard to their OM status should therefore be assessed, and the CPPL database must be established based on the interpretations of those analyses.

The CPPL constitutes a digital portfolio of electronic components. The CPPL contains the following:

1. Fundamental information on the electronic component on a summary tab, such as Manufacturer Part Number (MPN), company part number, brief description of the electronic component, Original Component Manufacturer (OCM), distributor, electronic component taxonomy path about its electronic component category and complexity level, the EU's Restriction of Hazardous Substances (RoHS) compliance, and lead-free data.
2. Logistical information on the electronic component (supplier selection criteria, lead time, customs procedures and custom clearance). The suppliers' merger and acquisition policies in the electronic component market are also monitored per category of suppliers, and their news about components are also followed up here. Taking this information directly from the external BOM obsolescence management tool and from the company's electronic component suppliers, enables the transfer of information to relevant process owners through the internal CPPL.

3. Detailed parametric information on the electronic component which contains electrical data and reliability data of the component (such as voltage, tolerance, operating temperature, storage temperature, failure rate, mean time between failure), and other comparably important information in connection with the component's electrical elements.
4. Package information such as mounting information (surface mount or through hole), termination style, case type, size, pin data, size, weight, and other relevant information referring to the component's logistics.
5. Supplier packaging information such as bulk, tape and reel, and other information relative to the component's bind and bundle.
6. Manufacturing information such as manufacturing data about maximum reflow temperature, reflow solder time, and other information concerning the component's fabrication.
7. Environmental, conflict minerals data, and chemical data on the electronic component such as lead-free status of the electronic component and EU RoHS compliance information, whether it is a halogen free, waste electrical and electronic equipment (WEEE); supplier status, EICC membership, item/sub-item mass data, material types, and other complementary information with regard to the component's relationship with the environment.
8. Risk analysis information on the electronic component such as part status (as an active, LTB, obsolete, NRND, preliminary phase of the electronic component lifecycle); part lifecycle stage (introduction, growth, mature, decline, phase-out, and obsolescence), estimated years to-end-of-life (EOL), and other corresponding information about the component's lifeline.
9. Documents of an electronic component, such as datasheets of the electronic components, design resources files such as the electronic component diagrams enclosed within design tools, packaging

information, datasheets in HTML format, CAD models, catalog of the family of the electronic component, picture of the electronic component, error reports of the electronic component, problems experienced with this component within the company, background story of the components, and the reason to cease utilizing this component as well as the search for its alternatives.

10. Application field categories of the electronic components in systems, such as electronic cards for interfaces, radars, and EMI/EMC filters.
11. Component quantities in inventory, and alternative component availability information acquired from the electronic component market.
12. Reasons why alternative components are used instead of obsolete ones, Not Recommended for New Designs (NRND), LTB, and their histories.
13. Information on which systems use the alternative instead of the original component.
14. The phase of the CADMID project lifecycle the electronic component is in, owing to the fact that other designers who will use the component will benefit from knowing which stage or time period the component is issued in the project lifecycle, and knowing who utilizes this component in which part of a project.
15. PDN and PCN notifications from the CPPL are forwarded to relevant process owners. PDN and PCN notifications are received from suppliers and through searching the BOM obsolescence management tool. The information resulting from such incidents are transferred to the CPPL, enabling all concerned to access such information about the component.
16. The information on quantities available in the company’s inventory, as well as their alternatives.

The CPPL must have the following properties:

a. A user friendly software interface that is easy and simple to use,
b. An electronic components’ properties filter, which includes, for instance, electrical or reliability data, the information of series or family of the components, part status (such as active, LTB, obsolete, NRND, preliminary phase of the electronic component lifecycle), number of logic elements or cells for FPGAs, number of Input/Output (I/O) information of an FPGA, Number of Gates of an FPGA, operating temperature, package case information, and supplier package information of the filter, and other parallel information to the electronic component’s distinctive characteristics.
c. A “BOM Manager” page to facilitate uploading and managing the company’s BOMs in a spreadsheet format. For instance, a page unique to every project can be hosted below “BOM manager” pages, accessible by all project managers and other process owners, providing revision information of electronic cards within this project. Subfolders for all assemblies and electronic cards can be created under this project folder, all the way down to files pertaining to the electronic components.
d. A document page, containing guidelines about electronic components, new releases of documents, OM-related documents, handbooks, and standards.
e. A comparison ability where various electronic components can be compared against one another,
f. A forum where CPPL administrators and process owners can communicate. This can also act as a platform for Frequently Asked Questions (FAQs) where explanations and discussions about electronic components can be displayed for reference. The advantage of this forum is that when a project member experiences

a problem about a given component, the accruing discussions will constitute valuable know-how visible to others using this component.

At present, process owners are only able to exchange information with regards to alternative and replacement components via e-mail. It would be ideal for them to have the capability to do so through automatic alerts to relevant process owners, putting an end to the difficulty of exchanging such critical information through e-mail. The approach proposed in this thesis enables to achieve this through PLM and CEP. With the help of the proposed CPPL which is the interface to manage electronic components used in the company, process owners can see the electronic component recommended alternatives information whenever necessary.

There are various methods to obtain information on electronic components used in designs as well as manufacturing. It is possible to obtain them through component distributors or websites of component manufacturers. This is information is obtained and updated by the obsolescence management team, i.e. the process owners of the new obsolescence management process. Thus, the electronic components in the CPPL will include potential alternatives scanned and entered from these sources by the obsolescence management team. This information will be used for replacing the component if the original in the BOM list cannot be supplied or found in inventory. With the use of the CPPL, the company can proactively produce a solution to obsolescence problems.

As mentioned in Chapters 2 and 3, the defense industry lost its power over COTS components, which account for more than 90 percent of the company's electronic components. This is due to the fact that COTS components become obsolete rather quickly in the commercial electronic market. In the CPPL, it is also necessary to monitor the market status of

COTS components, and it is important to define alternatives for COTS components.

Also, as mentioned in Chapters 2 and 4, it is crucial to monitor high complexity components throughout the period extending from concept design to manufacturing. The CPPL will enable designers to select components based on the information contained in the CPPL during SCH revisions or new electronic card designs.

When the company's different types of contracts are taken into consideration, the designer's choice of component influences the whole contract management process. It is therefore critical that electronic component selections are made from the CPPL as early as the design phase. Moreover, when an obsolescence problem is encountered related with a contracted equipment while providing maintenance services, OM solutions can be rapidly found from the detailed information contained in the CPPL. In support logistic contracts, malfunctions in equipment (products sold by the company to the customer) are related to the designer's choice of electronic component. This is also the case for availability-based (PBL) contracts. The reason is that performance of the product in such types of contracts is directly related to the reliability of the system. All support to be provided during the in-service phase of the products' lifecycle will influence contract costs. As an example, the optimization of maintenance and repair costs requires the prediction of the failure rates in the system. It is therefore critical that component selections are made from the CPPL, where relevant data is managed and refined during the design process.

## 5.3 Architecture of Complex Event Processing to Manage Obsolescence

Complex Event Processing (CEP) is a technology for managing and integrating information from distributed systems. The term was coined by Luckham et al. (1998). CEP systems continuously collect data from various sources about events within a company's processes, and use algorithms and rules to determine trends and patterns that combine them into complex events. The findings are then sent to the appropriate process owners (Leavitt, 2009). As such CEP is central to the integration of OM related processes. It allows process owners to specify the information they need and receive alerts in real time. There are several open source and commercial tools for CEP (Top 20, Open Source and Premium Stream Analytics Platforms, 2019; SAP, 2019).

The architecture proposed for CEP within the framework put forth in this thesis is shown in Figure 5.1. It consists of event producers, an event processor, and event consumers. Events refer to the movement of processes over a predefined workflow.

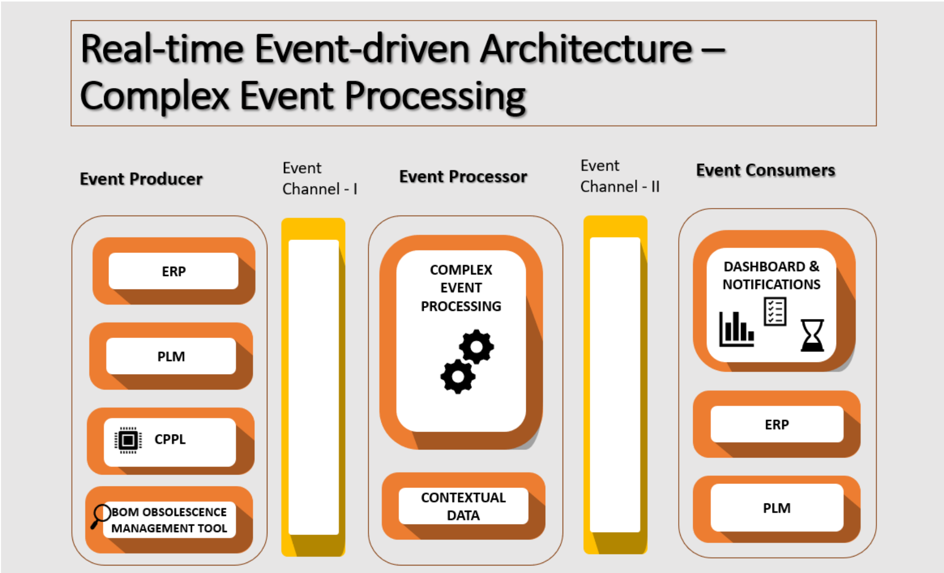


*Figure 5.1* Architecture for CEP to administer OM processes in the Company

Event producers are PLM, ERP, CPPL, and the BOM obsolescence management tool. Event consumers are PLM, ERP, and "Dashboards and Notifications" for process owners. The event processor is the integrator between event producers and event consumers. It detects patterns, relationships, trends, filters irrelevant events, enriches data and puts them in context.

The company's processes do not currently communicate with one another in real-time for the purpose of tracking electronic components within the framework of the CADMID lifecycle. In the proposed CEP system, the electronic components registered and used in the ERP, PLM, ECDTLs, and CPPL can be tracked, and with the help of CEP, events in these tools can be interpreted into necessary actions as they occur in the real-time.

With the help of CEP, the company will be able to establish an operational business framework in order to effectively interpret and administer electronic component events in its processes.

CEP enables instant tracking of components data. Considering that the five main obsolescence management related processes of the company (including the proposed new OM process) each constitute a cluster, it is a necessity for the company to establish channels of communication among these clusters. The CEP infrastructure unites these clusters, including the new OM process, in order to ensure the integration among these processes through a dynamic information flow. In other words, it is very critical to have an exchange of information and establish consistent channels of communication among departments of the five processes.

The event producers of this architecture include:

1. The company's ERP system and its processes (including MRP) which produce electronic component data.
2. The company's PLM system through which relevant subprocesses of the five main processes are transferred.
3. The BOM monitoring tool's external database.
4. The CPPL as an internal database.

Event channel 1 is a processing element that receives events from the event producers, makes routing decisions, and sends the input events unchanged to the event processor's target processing elements following routing decisions.

The event processor hosts algorithms to calculate the results of these events, providing an option to identify obsolescence problems while monitoring business processes as well as critical resources of the company. In the event processor, data from event producers acquire a context to find unique and meaningful ways to explain complex events. The electronic component supplier data are acquired from the ERP, the obsolescence data are obtained from CPPL and the BOM obsolescence management tool, and the data of process owners in the workflow are acquired from PLM. Accordingly, these data are processed by CEP algorithms and they obtain a context, which has a unique meaning for the OM process owners of the company.

The event processor transfers these processed contextual electronic component data through event channel 2 to the event consumers. It generates notifications on any potential obsolescence issue, including which electronic cards or assemblies are, can, or even could be affected by an obsolescence issue. This information is published on the event consumer's Dashboard and Notification interface as an alert for mitigation and resolution strategies to be considered.

The purpose of CEP is to analyze and react to events to solve electronic component obsolescence management problems by keeping process owners up-to-date.

The following section describes the fourth element of this framework, i.e. the "shell structure", and describes the details of the new obsolescence management process proposed in this thesis.

### 5.4 The "Shell Structure" and Obsolescence Management Process

The Shell Structure (Figure 5.2) aims to eliminate the OM related communication and integration deficiencies in existing processes. It incorporates the existing processes related to OM described in Chapter 4, as well as the new OM process proposed in this thesis.

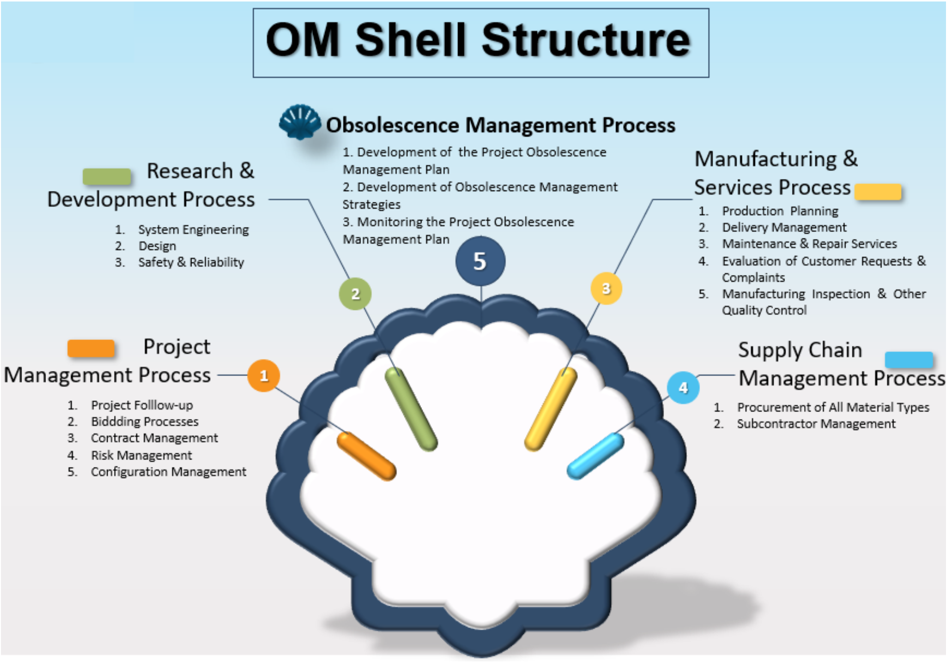


*Figure 5.2* Obsolescence Management Shell Structure

The Shell Structure was inspired by the protective shell of a shellfish, which protects it from outside interference. Likewise, the Shell Structure is to protect the systems, assemblies, and electronic cards produced and maintained by the company throughout their lifecycles. This is also the reason why each phase of a CADMID lifecycle is implemented. As explained in Chapter 3, CADMID consists of the “Concept, Assessment, Demonstration/Design, Manufacture, In-service, Disposal” phases. The environment where the shellfish exists can be likened to the phases of the CADMID lifecycle of products. The “Concept, Assessment, Demonstration/ Design, Manufacture” phases can be considered as the sea life of the shellfish; whereas the “In-service, Disposal” phases can be considered as the land life of the shellfish. In this OM shell structure, the company can safeguard the vitality of its products under the sea as in their CADM phases, and on land as in their ID phases. The Shell Structure preserves the vitality of existing processes, contributes to their endurance, while at the same time increasing the quality of the lifecycle, performance, and reliability of products. The Shell Structure aims to act as a protector of electronic components as project lifecycles make progress for the purpose of preventing potential OM problems. It aims to protect the company’s products as a shell with reactive and proactive strategies, mitigation and resolution approaches for OM problems almost like a shell protecting the pearl -the product- inside the shellfish.

Through the Shell Structure, the company can monitor its electronic components in their environment. The term environment here refers to each phase of the CADMID lifecycle.

To begin with, a CADMID lifecycle can be implemented for each main process within the company. For example, the project management process can benefit from each “environment” (i.e., phase) of the CADMID lifecycle and use them to categorize its operations. Under the four main processes, every subprocess within the company can use the phases of the CADMID lifecycle to administer tasks undertaken as described below.

- The project management main process covers and governs all phases of the CADMID lifecycle of a project, at the system, assembly, electronic card and even electronic component level,
- The design subprocess of the R&D main process covers and governs the CAD phases in the project lifecycles of the product,
- The manufacturing and services process covers the manufacturing - the “M” phase - of the CADMID lifecycle of the product, as well as the delivery management subprocess of the manufacturing and services process, which is the in-field lifecycle of the system - the “I” in the CADMID cycle,
- The supply chain management process covers the DM part of the CADMID cycle.

As shown in Figure 5.2, the Shell Structure consists of 5 processes: project management, research and development, manufacturing and services, supply chain management, and the new obsolescence management process. The new OM process consists of the following three subprocesses: the development of the Project Obsolescence Management Plan (POMP), the development of OM Strategies, and monitoring of the POMP.

The five main processes of the Shell Structure produce electronic components data in real-time. OM as a Shell Structure enables the flow of information with regards to electronic components to these five processes through CEP.

The following sections describes the new workflow within the Shell Structure enabling the detection of, making decisions on, and responding to OM issues.

The workflow among the processes within the Shell Structure is shown in Figure 5.3. This figure emphasizes the changes achieved by the framework through the addition of the OM process and its integration with the four main OM related processes. Thus, it shows the improvements in monitoring obsolescence when compared to the current situation described in Figure 4.2. The new workflow is described for each of the of the design phases: the concept design phase (Section 5.4.1), the pre-design phase (Section 5.4.2), and the critical design phase (Section 5.4.3).

The next section describes “The Concept Design Phase of the New OM Process”.

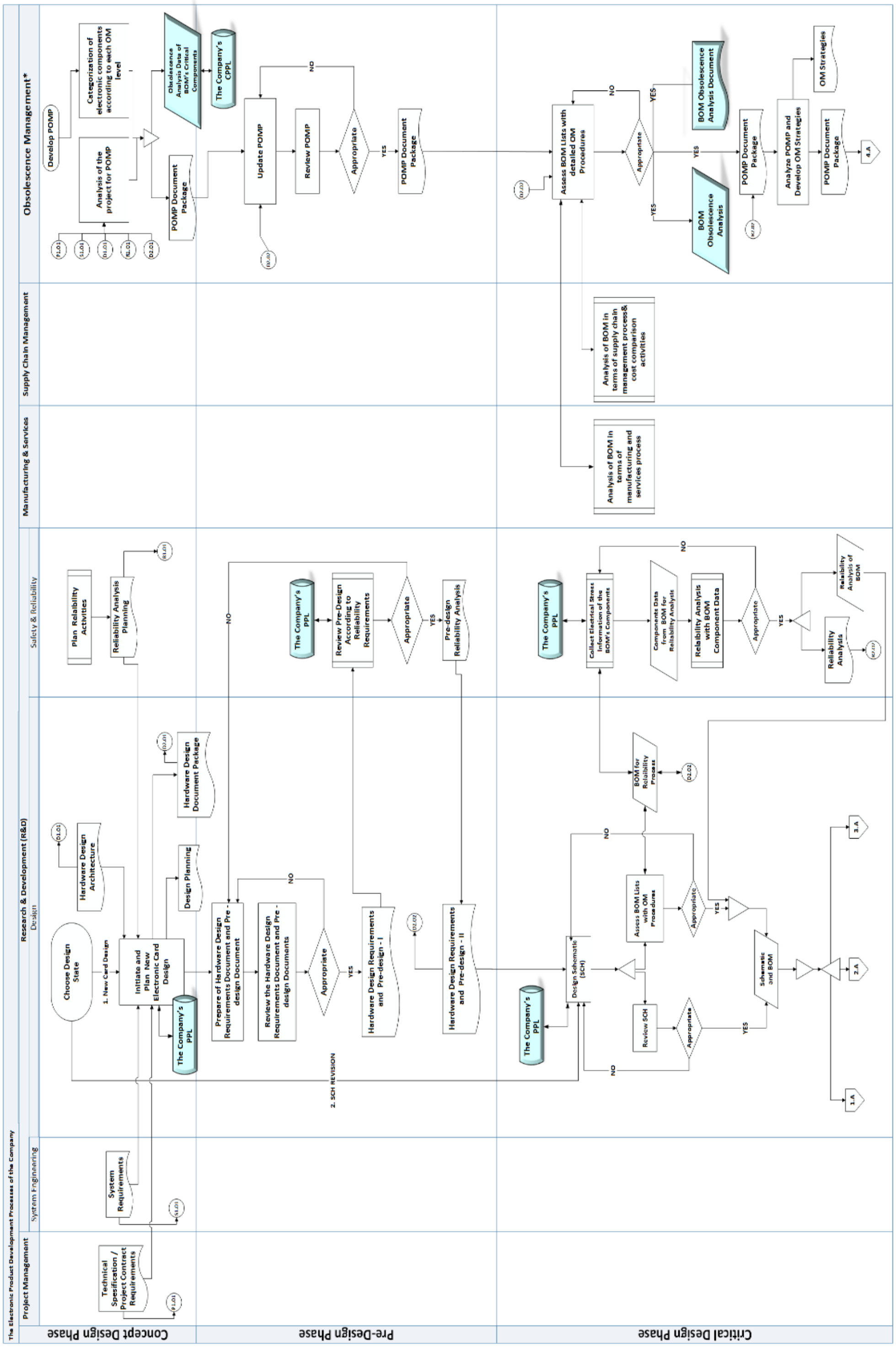


*Figure 5.3* Obsolescence Management Workflow under the Shell Structure to Monitor Flow of Electronic Components

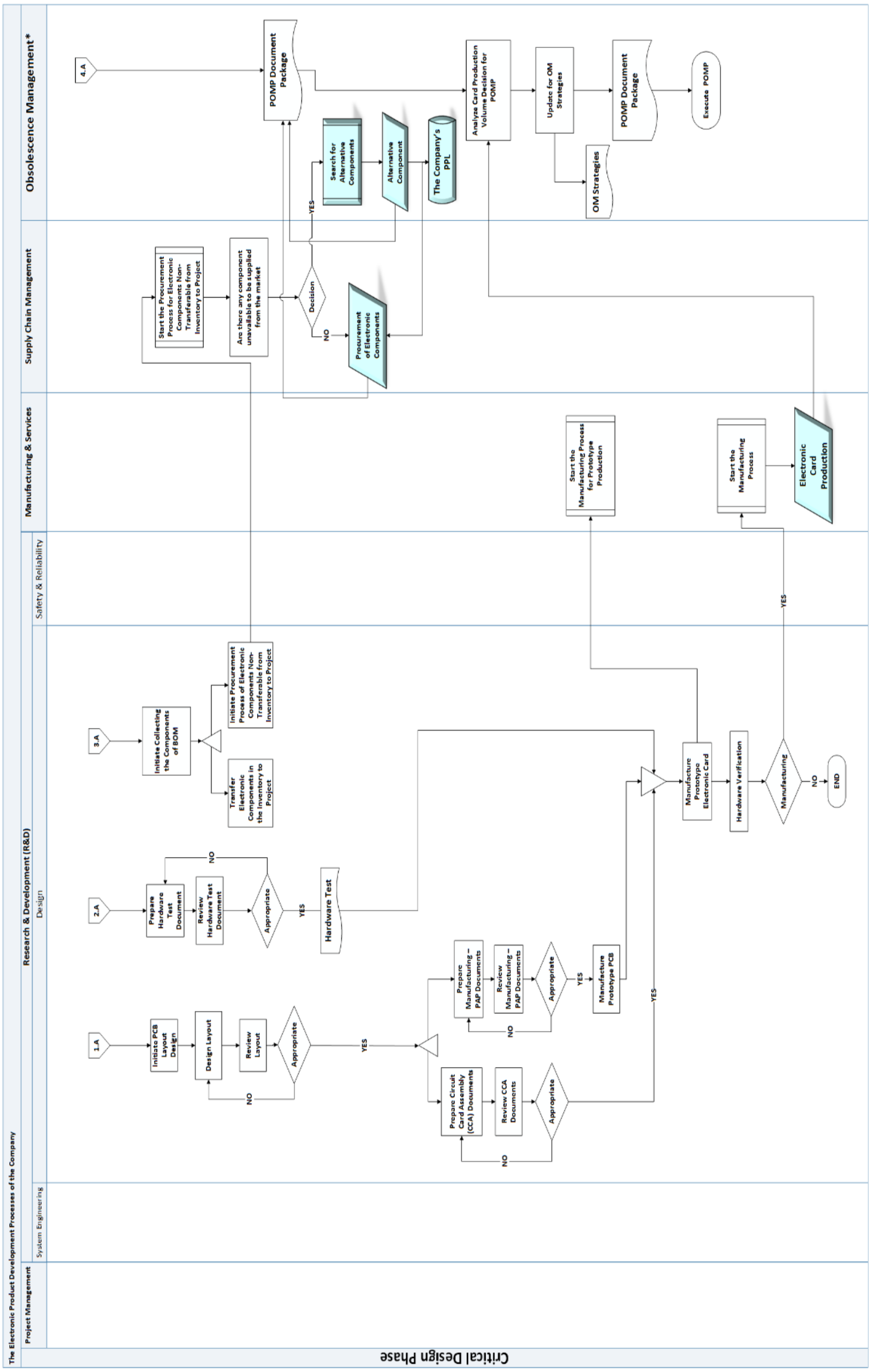


*Figure 5.3* Obsolescence Management Workflow under the Shell Structure to Monitor Flow of Electronic Components (cont'd)

### 5.4.1 The Concept Design Phase of the New Obsolescence Management Process

This phase includes three main processes: the development of the Project Obsolescence Management Plan, the development of obsolescence management strategies, and the monitoring of the Project Obsolescence Management Plan.

#### 5.4.1.1 The Development of the Project Obsolescence Management Plan

In the concept design phase, the first step is to “Develop a Project Obsolescence Management Plan” (POMP). The POMP manages the obsolescence of all electronic components in a product. The main objective of the POMP is to ensure that electronic components are available when they are needed, including sufficient component quantities for maintenance and repair services, and to avoid project delays and cost overruns.

A POMP must be prepared for each project because the requirements of each project are different from the concept design phase to the end of the project disposal phase. Thus, the POMP must be applied from the beginning of the concept design phase of the CADMID lifecycle, until the end of the in-field life of the electronic product; i.e., the disposal phase. If new components are included in the phases of the lifecycle, the POMP is updated to include these components.

In order to achieve electronic component level obsolescence management, the POMP must include all hierarchical levels of products, which are the system, assembly, electronic cards, and the components levels. It is necessary for POMP to follow up electronic components in the project's CADMID lifecycle within the POMP timeline. All revisions on electronic cards (SCH revision with PCB revision or SCH revision without PCB revision) are followed through the POMP.

Each project has a CADMID lifecycle and the CADMID phases are used to divide and control the POMP. Each electronic component of the project also has its own CADMID lifecycle. The manufacturing, in-service and disposal phases of electronic component are considered as "availability phases of electronic components based on production volume" as shown in Figure 3.1. Besides, "the availability phases of electronic components based on production volume" is defined under six lifecycle phases, which are introduction, growth, maturity, decline, phase-out and obsolescence. The six lifecycle phases of electronic component are placed both on the project's CADMID phases and the POMP timeline. This nested CADMID structure can be used to create timelines as reference points to schedule and monitor POMP.

For example, during the concept design phase of the project, an electronic component in its growth phase in the electronics component market is included in the project. Furthermore, this electronic component is in the category of high complexity. Over the years, the project has reached the end of the manufacturing phase in its CADMID lifecycle. In the POMP timeline, the project is in the manufacturing phase now. If at this point, the electronic component has reached its decline phase, which means the component is close to the obsolescence phase, the OM level of the electronic component must be re-evaluated in the POMP. Therefore, OM strategies will have to be updated for that component.

Furthermore, the POMP must consider the effect of technological developments in the electronic component market, and the technology roadmap of the company as described in Chapter 3, especially in relation to COTS.

In order to monitor and manage the POMP, it is necessary to create a set of controls which can be carried out by obsolescence management checklists which are documented in detail in the POMP.

The benefits of the POMP include the capability to address obsolescence risks in the hands of the right process owner or the right business partner at the right time and place. This includes improved communication with subcontractors, support to subcontractors to develop their capabilities in terms of OM, and developing OM strategies at the beginning of the project lifecycle. Within the scope of the project, milestones are determined in the POMP timeline for the electronic cards produced by the subcontractors. The BOMs given to subcontractors are also audited with the obsolescence management checklists periodically.

The development of the POMP consists of two subprocesses: the “Categorization of electronic components according to each OM level” (Section 5.4.1.1.1), and the “Analysis of the Project for the Project Obsolescence Management Plan” (Section 5.4.1.1.2).

#### 5.4.1.1.1 Categorization of Electronic Components according to each Obsolescence Management Level

In order to identify the scope of and the risks of obsolescence, which is crucial for the POMP, electronic components must be categorized based on their complexity levels as described in Chapter 2, and their levels of obsolescence in the project, which are reactive, proactive, and strategic levels, as mentioned in Section 3.7.

1. Reactive Management Level (RML): Under the RML, first, resolution strategies must be executed to provide prompt solutions to obsolete components. According to the revision type and the component's obsolescence state, resolution strategies can be defined under the POMP. For example, if an electronic components is detected to be obsolete at the critical design stage, and the alternative component is found to be compatible with the old component's form fit function, then the CCA revision is required only within the design subprocess. The obsolete component information in the CCA document is replaced with the one that is compatible to the original. The newly added alternative component will continue to be monitored under its appropriate OM level in the POMP.

2. Proactive Management Level (PML): At this level, critical electronic components must be identified and classified according to their criticality levels. Critical electronic components are classified as:

    i. Critical electronic components that are at risk of becoming obsolete,
    ii. Electronic components that will have insufficient quantities after obsolescence to satisfy the expected demand, and
    iii. Critical components that will lead to problems if or when they become obsolete.

After the identification of critical components based on the above three categorizations, their actual obsolescence events are prioritized. For example, during the process of "Assess BOM Lists with detailed OM Procedures", as shown in Figure 5.3, obsolescence studies are performed under the OM process. Then, components at the risk of becoming obsolete, NRND, or LTB as identified during the examination of BOMs, are sorted according to their levels of criticality. Accordingly, mitigation strategies and resolution approaches are developed under the POMP.

3. Strategic Management Level (SML): The SML uses:

    - Obsolescence data,
    - Logistical data (such as supplier selection criteria, lead time, and customs clearance of the electronic component),
    - Technology forecasting and technology road mapping, and
    - Demand forecasting, also known as business trending.

    SML allows strategic planning, life-cycle optimization, and long-term business case development for system support purposes. Design refresh planning (DRP) is the most significant and common approach in the strategic management of obsolescence. It determines the set of refreshes that maximizes future cost avoidance as described in Chapter 3. Technology roadmaps should be identified, and these roadmaps are reflected by the company's internal targets, timing and budgeting limitations (Chapter 3). When deciding OM strategies under the POMP, preparing review lists for obsolescence issues in the project lifecycle is vital. Based on the examination of BOM, whether or not DRP is required can be established.

Furthermore, taking the revisions of the electronic card into account, affected processes and documents can be accessed by process owners of the project. After that, OM levels are considered for selecting mitigation strategies and resolution approaches depending on the revision type. Replacing the electronic component due to revisions is a significant factor in the calculations of performance using predefined performance criteria, as discussed in Section 4.3.1 in “The Concept Design Phase”. Thus, controlling and managing design revisions that may result from obsolescence is a critical success factor that significantly affects project performance and DRP. By virtue of the POMP, future obsolescence risks can be identified, and strategies can be developed in a way that requires a minimum number of revisions.

Another step of developing a POMP is to analyze the project information to develop OM strategies for projects, which is discussed below.

#### 5.4.1.1.2 Analysis of the Project for the Project Obsolescence Management Plan

The process of “Analysis of the project for POMP” is initiated simultaneously with five inputs from the other four main processes. The inputs from the four main processes involve:

1. The “Technical Specifications Document or Project Contract Requirements Document” from the project management process,
2. The “System Requirements Document” from the system engineering subprocess of R&D,
3. The “Hardware Design Architecture Document” from the design subprocess of R&D,

4. The "Hardware Design Document Package" from the design subprocess,
5. The "Reliability Analysis Planning Document" from the safety and reliability subprocess of R&D.

The "Analysis of the project for POMP" and "Categorization of electronic components according to each OM level" results in the "POMP Document Package" and "Obsolescence Analysis Data of BOM's Critical Components".

Moreover, "Obsolescence Analysis Data of BOM's Critical Components" is assessed via the CPPL. If the electronic component is not included in the CPPL (if it is a new component in the design), it must be defined in the CPPL. The CPPL is also updated continuously through the BOM obsolescence management tool as an external database. The CPPL checks the obsolescence information of components through the use of the BOM obsolescence management tool, and the websites of distributors or original component manufacturers, and updates the component information in the CPPL.

In the design subprocess of R&D, when "Initiate and Plan New Card Design" begins, designers choose electronic components from the CPPL. With the help of the CPPL, the company's electronic components are monitored against obsolescence because designers are able to use electronic components which have active lifecycles.

The CPPL also contains the list of critical and high complexity electronic components contained within the "Hardware Design Architecture Document" and their possible future alternatives will be used in the design subprocess. Obsolescence of FPGAs, LEDs, and connectors is critical for projects, and for that reason, obsolescence of such critical components is dynamically monitored in the CPPL.

All revisions, meaning all modifications in electronic components performed on electronic cards during projects, must constantly be monitored under OM strategies,  while additional OM approaches under the POMP must be updated in relation to these components.

In terms of the revision state, if the second design state is necessary, which is the schematic revision state with PCB revision, and especially if it is a component that is a new alternative and undefined in the CCA document, OM strategies can be developed within the context of the project. The alternative component is also included in the project's POMP. Further, the reasons why the component is used as an alternative and its advantages for the project must be included in the CPPL.

In electronic component replacements with the SCH revision state without PCB revision, as in the case of  Pin-to-pin compatible (form-fit-function) alternatives, POMP documents such as OM strategies reports, the BOM obsolescence management report and OM strategies need to be updated with regards to the newly-added replacement component's obsolescence management strategies.

It is critically important for the company to keep track of revisions in existing designs, electronic cards, assemblies and systems with regard to OM in conjuntion with a Design Refresh Plan (DRP), as  well as to develop a technological roadmap and plan accordingly. Without an OM process for monitoring component replacements due to SCH revision with or without PCB revision,  which are often caused by obsolescence, there will be grave problems that increase exponentially as described in the example presented in Section 4.4. Design refresh dates need to be established and monitored. If DRPs are managed and controlled in an efficient manner, SCH revisions with or without PCB revisions can be avoided proactively, and hence future problems in the supply chain, and system engineering processes can be avoided.

Electronic component changes in BOM’s and CCA documents can be monitored via DRPs, because the history of CCAs show the revision histories of the designs. DRP recommendations and calculations of performance are also conducted based on past information of revisions on electronic cards. Revisions performed based on cost calculations and obsolescence have significant impact on the cost of design. With OM in place, there would be less revisions; hence, by using a DRP, it will be possible to engage in a design refresh before it is too late and prevent the possibility of failing to find components to replace the obsolete ones.

Furthermore, to determine a suitable obsolescence strategy under the POMP, projects must be analyzed according to contract types stemming from the project management process. Contract types can be classified according to their clauses and characteristics related to safety and reliability requirements, warranty periods, in-field life of projects, and risk assessment - high risk to low-risk projects, cost of the projects, value gains, and manufacturing volumes.

The company's in-field products require high sustainment costs, such as the cost of operating, maintaining, and supporting a fielded system during its long field life due to the nature of military systems. The OM clauses currently used in contracts (Chapter 2) are not adequate, as the contract management subprocess is unable to determine the scope of OM and use it to estimate contract costs. OM clauses are not prepared according to the POMP at the beginning of CADMID.

Within the scope of the POMP, OM related costs can be estimated more accurately, due to the fact that the warranty period is also part of the POMP. Hence, the company is adequately prepared for the risks arising from the obsolescence of electronic components.

Besides, defense companies worldwide are now shifting towards Performance Based Contacts (PBL), and the capability analysis of projects, and due to that reason, the reliability analysis of electronic components has become crucial. Since the company has a built-in infrastructure for PBL contracts with the help of POMP, the company can meet the high performance (reliability) criteria defined in such contracts.

High-reliability systems require comprehensive and detailed performance studies and analyses. The requirement of high reliability increases the cost, and thus has a direct impact on the chances of being awarded a bid. In this matter, the POMP can be used to predict the total project cost more accurately. Furthermore, with the help of analyzing the contract types, obsolescence-related clauses can better be determined under the POMP, total product costs can be reduced. Likewise, by identifying alternatives for critical components under the POMP, it is possible to reduce total product costs.

For instance, when the company develops an obsolescence strategy/approach for each component under the POMP, the number of components to be used in the project can be estimated more accurately. Additionally, this method can prevent the purchase of excess components for the maintenance and repair services of the project. Therefore, the initial overestimation costs can be avoided. On the other hand, taking into account such analyses for contracts, the whole life cycle cost of the project can be anticipated more accurately based on the duration of the project, and the technical specifications included in the contract type.

Moreover, to determine a suitable obsolescence strategy under the POMP, projects must be analyzed according to the production volume of the systems, which is determined by the production planning subprocess. According to production volume, the MRP is used for buying electronic components and deciding OM strategies such as Life-time Buy (LFTB) and Last Time Buy (LTB). Besides, the production volume, and the type of contract and its clauses contained in the POMP enables the management of supplier relations. Based on such analysis of the project, mitigation strategies, such as partnership agreements with suppliers, as described in Chapter 3, are implemented where necessary in the POMP.

Another important consideration when developing an OM strategy, is the determination of when and where an electronic component is used within a system, including its use in ongoing projects and their assemblies as well as electronic cards. Movement of electronic components within projects makes it difficult to see where they are in terms of the CADMID lifecycle phases, or in which obsolescence state they are in the life cycles of each of these complex systems. As the completion and fielding of projects take many years, electronic components should be monitored in each phase of product lifecycle of each projects in real-time in order to identify the risks of obsolescence.

As mentioned in Section 5.4.1.1, the six lifecycle phases of electronic components are placed on the project's CADMID phases on the POMP timeline. This nested CADMID structure can be used to create timelines as reference points to schedule and monitor POMP. The CADMID lifecycle in Figure 5.4 represents the system lifecycle of the product, as well as nested CADMID sub-system lifecycles for electronic cards used in assemblies and systems, and the electronic components of these cards.

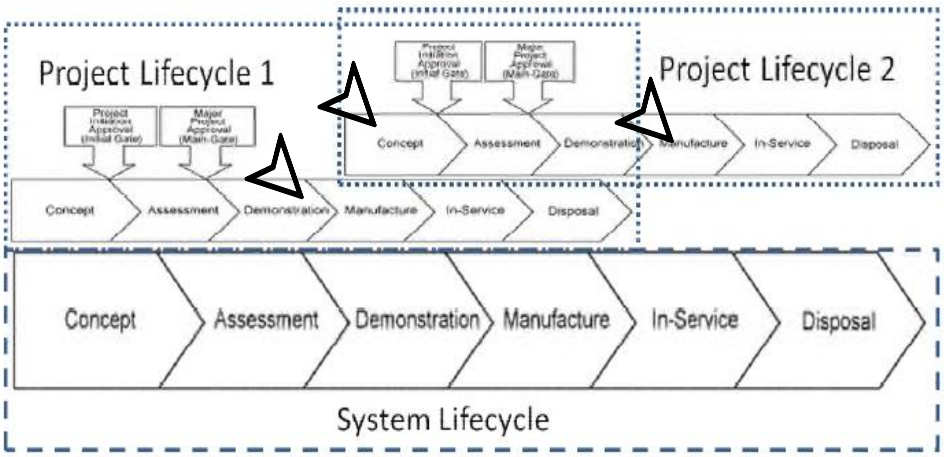


*Figure 5.4* CADMID Nested Project’s Lifecycles (BS:EN:62402:2007)

The arrows in Figure 5.4 represent the continuous flow of electronic components in each CADMID phase. The electronic components for the company’s products are procured for projects and recorded in the ERP system at the beginning of the project life cycle. As they used, they are deducted from inventory. However, in the CADMID cycle of the product, the CADMID cycle of these components is unknown. Therefore, it is crucial to track the nested lifecycles of projects.

When ordering electronic components for the project, evaluating and monitoring the project phases and the component's own lifecycle phases will play an important role in the procurement process. If the CADMID lifecycle of the project and components’ lifecycle during procurement are managed on the timeline of the POMP, the OM information of the components in the procurement subprocess can also be monitored within the scope of the project. In this way, the procurement subprocesses of the company are strengthened. Thus, the company's bargaining power for components clusters to be purchased is increased. Project's lifecycle phases also determine the inventory quantities of electronic components, and their follow-up enables the reduction of the inventory holding costs due to overstocking, as well as the costs incurred due to the unavailability of components.

#### 5.4.1.2. Development of Obsolescence Management Strategies

OM strategies are developed according to the hierarchical levels of projects (i.e. system, assembly, electronic card, and electronic component levels), the categorization of electronic components according to each OM level, and the analysis of the project for POMP. The OM strategies of the project must be updated in the "POMP Document Package" as shown in Figure 5.3. So long as the BOM list is generated following the schematic design during the critical design phase, it is possible to develop OM strategies in relation to any component, taking into account the issues and criteria described in Section 5.4.1.1 for the development of POMP. Strategies must be updated in the POMP Document Package (POMP DP) in all phases of the design subprocess.

#### 5.4.1.3 Monitoring the Project Obsolescence Management Plan

In order for the POMP to be sustainable, electronic components must be monitored constantly. CEP is used for monitoring the obsolescence sate of electronic components and posting alerts to relevant process owners.

Furthermore, the monitoring of supply chain, and manufacturing processes of electronic cards by subcontractors provide inputs to the POMP. In order to avoid the risks of the joint ventures with subcontractors, supply chain management, manufacturing and services, and design R&D processes must be managed through an obsolescence perspective to provide inputs for mitigation and resolution options in every phases of the lifecycle of products. The OM of electronic components and requirements arising from supply chain activities with subcontractors must be determined, and OM checklists must be prepared to control subcontractors. The checklists must include the procurement activities of the supply chain management process, and OM information of electronic components must be collected and monitored through these checklists. This also necessitates the continuous review of the BOM lists given to subcontractors. OM checklists are included in the POMP.

As explained in Chapter 2, the company supports and guides its subcontractors, including the exchange of electronic components between the two companies. With the application of the POMP subcontractors can be provided with early assistance regarding component obsolescence strategies, thus reducing obsolescence risks and project delays.

### 5.4.2 The Pre-design Phase of the New Obsolescence Management Process

The pre-design phase begins with the “Update POMP” process. When a new component is added to the project in the pre-design phase, it is evaluated in the POMP, and added to the CPPL database. The “POMP Document Package” has all the plans and strategies for obsolescence management of the project. At each design phase, it is used to update the POMP of the project.

At the beginning of the pre-design phase, the POMP is updated according to “Hardware Design Requirements and Pre-design-II”. The checklists of the POMP begin to take form in the process of “Update POMP”.

The elements of the “Hardware Design Requirements and Pre-design-II” document also includes the pre-design reliability analysis output of the safety and reliability subprocess. For this reason, during pre-design, using the safety and reliability analyses information of components integrated until this phase can solve potential POMP issues in the system, or can also trigger the re-assessment of these component during the pre-design phase. The “Review Pre-design According to Reliability Requirements” safety and reliability subprocess in R&D is carried out in conjunction with the CPPL administrators. After completion of the review of the POMP at the pre-design phase, the POMP is updated in the “POMP Document Package”.

### 5.4.3 The Critical Design Phase of the New Obsolescence Management Process

The critical design phase begins with the process of “Assess BOM Lists with detailed OM Procedures” under the new OM process. During this process, OM strategies are formed based on the inputs from other four main processes. Inputs of this new process include the following as shown in Figure 5.3:

1- “POMP Document Package”,
2- The BOM data of the schematic,
3- Analysis of BOM in terms of manufacturing and services process,
4- Analysis of BOM in terms of supply chain management process and cost comparison activities on electronic components from suppliers.

During this process, all electrical components in the schematic are checked against an obsolescence status. The inputs to this process come from the "Analysis of BOM in terms of manufacturing and services" subprocess from Manufacturing and Services, and "Analysis of BOM in terms of supply chain management" subprocess" from Supply Chain Management. If new components are to be added or removed from the BOM, it must be done in "Review Schematic" and "Assess BOM Lists with OM Procedures" subprocesses in R&D. When a new component(s) is added to the BOM in the "Design Schematic", it will be evaluated in the OM process and then added to the CPPL database. During the subprocess of "Collect Electrical Stress Information of Components" under the safety and reliability subprocess, process owners check the electronic components data related to reliability from the CPPL.

As stated in Chapter 4, ECDTLs are currently only checked every six months. With the new OM process, the CPPL administrators constantly monitor the components and perform checks on ECDTL libraries. Moreover, the existence of pre-defined OM procedures under the OM process requires BOM control during the subprocess of "Assess BOM List with detailed OM Procedures". In line with these pre-defined OM procedures, the BOM is controlled via a checklist over the POMP. Concurrently, the alternatives to be defined in the CCA documents need to be checked at this phase. If there are alternatives outside the CPPL identified by the designer, these alternatives must be evaluated by the subprocesses of both manufacturing and services, and supply chain management processes. The selected components are then registered in the CPPL. As the components can be queried by relevant process owners over the CPPL, OM-related information on the components is shared by all concerned.

If the subprocess of “Assessing BOM with detailed OM procedures" (in the new OM process) provides an appropriate result, outputs of this process form the “BOM Obsolescence Analysis” data as well as the “BOM Obsolescence Analysis Document - II”. These become inputs, in addition to the element of “Reliability Analysis Document” from the safety and reliability subprocess, to the “POMP Document Package”.

After updating the “POMP Document Package”, the process of “Analyze POMP and Develop OM Strategies” begins under the new OM process. During this process, BOMs in the systems, assemblies, and electronic cards of the project are analyzed within the scope of POMP. For instance, if a component is identified by the OM process at high risk of becoming obsolete (such as at the mature phase of its production volume in the market), then OM strategies will guide actions that follow as discussed in Chapter 3. The output of this process are “OM strategies”. The outputs of this process are also included in the “POMP Document Package”.

As mentioned in Chapter 4, a comparison of the components based on their years to end-of-life (EOL) properties is performed for the schematic design. However, the information is only stored in the “BOM Obsolescence Analysis Document”. For example, obsolescence risks can be high for a component in its maturity phase, which should be monitored, but is not. With this new OM process, components in their maturity phase will constantly be monitored in the CPPL, and CEP notifies and alerts relevant process owners on modifications pertinent to the component, and incoming LTB information. In that way, process owners in system engineering, project management, and supply chain management can reach up-to-date information about the component and act in accordance with the POMP.

The “Initiate Procurement Process for Electronic Components Non-Transferable from Inventory to Project” subprocess of the design process triggers the subprocess of “Start Procurement Process for Electronic Components Non-Transferable from Inventory to Project” in the supply chain management process. If alternative components are available in the market, their procurement is started. The “Procurement of Electronic Components” data is included in the “POMP Document Package” and also stored in the CPPL. If there are no components available in the market, the subprocess of “Search for Alternative Components” begins under the OM process. Alternative components are sought from internal and external electronic component databases. External electronic component databases are reached through the company’s external BOM Monitoring Tool, and the websites of electronic component suppliers and distributors. Alternatives are selected by the designers. The alternatives are added to the “POMP Document Package” and the CPPL.

As described in Chapter 4, during the procurement subprocess of supply chain management, designers are consulted on whether there are alternatives with shorter lead times in place of the components with longer lead times in the BOM. With CEP and the CPPL, an exchange of information is ensured about the manufacturers, distributors, and lead times of components. That is how failures in the communication between designers and supply chain process owners can be avoided, as they will be able to make earlier and more informed decisions about components. Lead times of components can be noticed much earlier, and alternatives can be designated faster.

The electrical stress values (voltage, current, temperature) of components, the BOM data are sent from the “Collect Electrical Stress Information of Components” to “Assess BOM Lists with OM Procedures” (a subprocess added to R&D) for the purposes of reliability prediction analysis. Project-based records on the reliability prediction analyses from each different BOM will remain unique even when different projects involve different types of components. This means that even though components on the circuits can be the same in various systems, the electrical stress values in the circuits will be different and show different electrical characteristics. Consequently, the project-based reliability prediction analyses should be recorded in the CPPL separately for each BOM. POMPs must be shaped by components in projects, whereas OM strategies should be shaped by reliability prediction analyses. At this stage, the OM process owners must co-operate with those in the safety and reliability process while refreshing the POMP document package.

Once the “Hardware Verification” process in R&D is complete, the prototype card design, manufacturing, reliability documents, and documents on other processes are approved, the decision about “Mass Production” has to be made. If the answer is “Yes”, the process of “Start Manufacturing” is initiated under the “manufacturing and services” process for the verified electronic card. The output of the subprocess of “Start the Manufacturing Process” is the “Electronic Card Production” data. This data is an input of the “Analyze Card Production Volume Decision for POMP”. During this process, the production volume is analyzed for POMP, and future OM strategies are considered according to the production planning subprocess under the manufacturing and services process. Based on the MRP results from the production planning subprocess, OM strategies are updated during the process of “Update for OM Strategies”. The outputs of the “Update for OM Strategies” are included in the POMP DP.

In the proposed OM process, new alternatives must be defined for obsolete or obsolescence threatened components in the BOM. While identifying alternatives, priority should be given to components in the company inventory and then to those registered in the CPPL.

Depending on the design state, the POMP is developed or updated. Within the context of the project's contract management and system requirement specifications, the POMP DP is a vital document package that should be controlled and updated dynamically during each design state, with the contributions of the five main processes. This POMP Document Package will be valid from the project's concept design until its disposal. For this reason, the POMP should constantly be kept up to date with review checklists.

## 5.5 Discussion

The existing processes of electronic product development and the electronic components used throughout their subprocesses (as described in Chapter 4) are currently not being monitored along the CADMID lifecycle of projects. This, as a consequence, gives rise to planning errors and loss of time measured in months for projects, resulting in monetary losses. The mismanagement of electronic components, and the additional costs fueled by the lack of OM procedures directly focusing on electronic components lead to a situation where the costs of design, manufacturing and services as well as supply chain exceed what was planned in the beginning.

In light of the shortcomings described in Chapter 4, the framework integrates processes where electronic components are monitored, checked, and tracked at each phase of the lifecycle throughout the project duration. The framework encompasses the extension of PLM, the formation of

CPPL, the introduction of CEP, and the Shell Structure with the new OM process. The new OM process as part of the Shell Structure is to operate alongside the main four OM related processes. It covers all electronic components for obsolescence monitoring and control, and hence the determination of reactive, proactive and strategic OM levels, and OM strategies. In order to achieve this, it is necessary to develop a POMP with detailed and realistic estimates of OM risks in electronic components, so as to cover nested CADMID lifecycles of the project, from the Concept phase to Disposal.

Within the framework, another imperative requirement has been identified as the lack of a confirmed and standardised company's preferred part list (CPPL) for electronic components. Beginning with the concept design phase during product development, the CPPL constantly manages and monitors electronic components, and ensures the progressive utilization of components in their maturity or near obsolescence phase, based on production volume. Currently, for electronic components that are in their maturity phases, registered as active in the production volume curve, and with fast approaching PDN and LTB notifications, it is possible to overlook their discontinuance. By creating an internal CPPL, it is possible to continuously update and manage electronic components through the OM process.

The OM focused framework enables interdisciplinary bonds among the main processes of the company through the Shell Structure.

### 5.5.1 Breaking Barriers with an Obsolescence Management Team

To manage the OM process activities, an "Obsolescence Management Team" (OMT) must be established.

The OMT uses the following tools for managing the OM process:

1. ERP,
2. PLM,
3. CPPL as an internal database,
4. BOM Monitoring Tool as an external database, and
5. Complex Event Processing (CEP).

Departmental silos are known to be troublesome for a majority of organizations regardless of their size. Considering the enormous size of the company, the integration proposed by this framework can be challenging. The OMT acts as catalyzer to destroy the silos and resolve communication deficiencies.

OM as a Shell Structure must achieve good inter-departmental interaction and collaboration. The exchange of information and cooperation between the OMT and the process owners of other OM related processes is certainly a critical aspect of the proposed framework.

Individual undertakings to mitigate the risk of obsolescence leads to lack of transparency and communication described in Chapter 4. Obsolescence management strategies should be carried out with the contributions of all departments. The problems associated with obsolescence must be managed by the OMT, and the strategies/approaches must be determined collaboratively.

Top management must support the implementation of an obsolescence management plan and form the OMT that manages, coordinates, controls, and evaluates obsolescence management activities within the company. This team should include design engineers, manufacturing and planning, safety and reliability, and finance experts, business analysts, data science specialists, supply chain specialists, and personnel with an R&D background who are also experienced in business administration as well as project management.

In order to decide which obsolescence management strategy/approach will be applied in the design phase, a hardware design engineer must be part of the OMT for technical expertise in electronic card design. This OMT member will review BOM data and evaluate it in terms of design requirements. Furthermore, this member should monitor the alternatives used in BOMs and alternatives in the CPPL by communicating with the card's designer. This monitoring is kept up to date by use of the CPPL.

The CPPL is formed and managed by the OMT in the company. On the other hand, the management of the CPPL is performed in conjunction with the Design Department with inputs from safety and reliability engineering, system engineering, manufacturing and services, and supply chain management processes. All electronic components are controlled with the help of these processes. The obsolescence mitigation and resolution strategies are unique to each project based on their scope. Although the CPPL covers all component and obsolescence information, all the project's process owners must be involved when the POMP prepared.

The OMT needs a team member from the manufacturing and services process to take necessary precautions. For instance, technical expertise is essential for the heat treatment of the alloys of components, or the rework of components on electronic cards. This technical expertise will also increase the safety and reliability when a printed circuit board (PCB) is assembled in the device.

The production planning engineer has the vital role of deciding to make the final purchases of obsolete components, or bridge buy decisions, or deciding the quantity of components needed in the future.

It is necessary to assess the effects of obsolescence on the total cost of the project, especially to manage contract processes during bidding. Therefore, a member from the Finance Department must be in the OMT.

Business analysts play a central role in ensuring the harmony between the capabilities of information technologies used in the OM framework and the needs of the company's departments. A business analyst can act as an interpreter by collecting and evaluating the information requirements of departments, and undertaking the business analysis activities according to the OM process.

There is a need for a data science specialist to process the collected component usage data and to extract component information from the various internal databases. These component usage data sets consist of customer feedback, after-sales services, and component usage data patterns within the company’s processes. Consequently, a data science specialist can develop predictive models, using data mining models based on these data sets. The data science specialist will work closely with designers and planners, and achieves collaboration with project management and the company’s R&D teams regarding components’ technical information.

The supply chain specialist coordinates the supply chain activities related to committing the company resources to purchasing components, developing supplier relations, developing bid packages, proposal analysis, and developing contracts according to reports from data analysis. Besides, the supply chain specialist is key when making partnership agreements with suppliers on critical components by measuring and reporting key performance indicators from component data extracted and analyzed from multiple sources in the company. This role is responsible for developing and executing supply chain plans for the obsolescence management process, and also improving supply chain's operational goals taking into account obsolescence issues.

Formal policies and procedures are necessary in order to ensure the implementation of the OM framework. The following section discusses OM policies and procedures.

### 5.5.2 Obsolescence Management Policies and Procedures

In order for the company to implement the new OM framework, formal policies and procedures are required. Top management needs to establish and approve new policies and procedures, supporting and enforcing the framework to ensure its adoption and operation in the company.

Policies should enforce the development of POMPs for each project as well as the implementation of OM strategies.

Procedures must be established for the formal workflow for OM, and the responsibilities of process owners in the Shell Structure. Procedures are also needed for the management of CPPL, PLM and CEP.

## 5.6 Conclusion

This chapter has described the extension of the Product Lifecycle Management (PLM) scope in the company, the establishment of the company’s preferred part list (CPPL) and standardization of the electronic component libraries, complex event processing (CEP) to administer the obsolescence management process, and the concept of obsolescence management through a Shell Structure. These are the elements of the OM framework for the company.

The implementation of this framework requires the establishment of an interdiciplinary OMT. Currently, OM issues are dealt with by a small group under R&D. Ideally a new unit as a line function must be formed to manage and coordinate OM activities.

This framework also necessitates the development of formal policies and procedures that set and enforce the mechanisms for OM.

# CHAPTER 6

# CONCLUSION

## 6.1 Overview of the Obsolescence Management Framework

Electronic components are used almost in all projects of the company and can be seen as the building blocks of the company's products. Therefore, the obsolescence management of electronic components must start at the concept design phase of the CADMID lifecycle, and be integrated with the other processes, which are project management, research and development, manufacturing and services, and supply chain management. Undetected obsolescence issues, especially during the initial phases of project lifecycles lead to failure in enforcing resolution approaches or mitigation strategies in time, and hence give rise to a snowball effect that can give rise to monetary losses reaching millions of dollars even in a single project. More importantly, attempting to only reactively resolve obsolescence issues is an open invitation for irreversible time losses. Thus, the company must administer each project through an obsolescence management perspective.

The framework proposed in this thesis puts forth the extension of the PLM scope in the company, the establishment of a CPPL and standardization of electronic component libraries, the introduction of complex event processing to detect obsolescence and alert relevant parties, and a Shell Structure, (including the new OM process), that unifies all OM related processes within the company. The above stated elements of this framework enable the company to integrate OM activities and develop OM strategies to cope with obsolescence.

## 6.2 Implications of the Obsolescence Management Framework

Products in the defense industry are often complex systems, developed a maintained through elaborate and complicated business processes. Throughout these processes the obsolescence of electronic components must be managed like “clockwork” during the CADMID phases of projects, starting from concept design to the product’s in-field phase, until its disposal. With the extension of the scope of Product Lifecycle Management (PLM) in the company, it is possible to keep records of each process as well as the role of project members in each project. Through the extension of PLM, which was formerly only used for design processes, to all processes of the company, integration and traceability is achieved.

The establishment of the CPPL and the standardization of all component libraries eliminates duplications and redundancies in the existing libraries of the company (ECDTLs and ERP). The lack of a CPPL prevented the accurate determination of obsolescence threatened components. The CPPL enables all historical data related to any component to be accessed, as well as information on alternative components. Once an alternative is designated for a component with the new CPPL integration, designers using the component are able to access information about the alternatives specified by other designers, saving precious time which would be wasted on a tedious search for a viable alternative. In conjunction with this, the CPPL allows process owners to quickly respond to any modification or discontinuance notification of an electronic component.

The extension of PLM and the establishment of the CPPL also enable better project management. For instance, contract requirements can be determined more precisely in light of the knowledge of the CADMID lifecycle phase in which electronic components are, signaling future obsolescence issues. Moreover, this will affect the maintenance and service contract clauses, and the cost of services to the customer. A better determination of these costs will give rise to advantages when the company is bidding for new projects.

Complex Event Processing (CEP) enables process owners in project management, research and development, manufacturing and services, supply chain management, and obsolescence management to be alerted about the status of electronic components. The algorithms in complex event processing use data from the company's ERP, PLM, CPPL and BOM Obsolescence Management tool, including manufacturing analysis of the electronic cards, system engineering, and safety and reliability analysis. Dashboards and obsolescence notifications are created to warn relevant process owners, who can then develop OM strategies to reduce the impacts of obsolescence.

The new Shell Structure enables the protection of electronic components used in products, comparable to that of a shellfish protecting the pearl at its core. Regardless of the phase of lifecycle they might be in, electronic components are continuously monitored, potential risks are identified, and future losses are minimized, as the company is able to foresee obsolescence risks and manage them accordingly.

As mentioned in the obsolescence management example in Section 4.4, currently obsolescence issues can remain unresolved for a year, giving rise to irreversible delays and costs. The proposed OM framework enables obsolescence problems to be recognized in real-time, and the detected problem is automatically shared with relevant process owners.

In the current situation, even after receiving a notification about the obsolescence problem, it took weeks to identify which electronic cards used the obsolete component, and notify all designers who used this component in the electronic cards in their projects. With the new framework, for example, if an alternative component is required for 30 electronic cards out of 80 electronic cards, this issue is immediately relayed to the relevant process owners through CEP. It will no longer take weeks to investigate who is responsible for which electronic card and reach the relevant process owner as mentioned in Chapter 4. Furthermore, if an alternative component has already been defined in the CPPL, it can be used directly. In other words, instead of searching for a suitable alternative component for weeks or days, an alternative component that has been approved and included in the CPPL can be used. This means that the investigation for a suitable alternative is reduced from weeks to days.

Currently, sending obsolescence information to all designers using the component consists of sequential steps. First, obsolescence information is obtained from the company's ERP, and all relevant process owners are identified. Then, an obsolescence alert is transmitted to the relevant process owners through e-mail. Now, with CEP, obsolescence alerts can be sent automatically in real-time.

Presently, obsolescence issues are often realized by chance. With the new OM framework, it is now possible to follow-up each of the company's approximately 12,000 electronic components, and monitor critical components at risk of obsolescence. Hence, proactive obsolescence management strategies can be adopted, significantly reducing the negative impacts of obsolescence on time and cost. Such monitoring is also likely to reduce the need for design refreshes, which is a time consuming and costly activity.

The framework also affects the company's relationship with its subcontractors and suppliers. Under this new framework, obsolescence information can proactively be shared with subcontractors, including information on critical components obtained by measuring and reporting key performance indicators from component data extracted and analyzed from the company's multiple data sources. This can also change relationships with suppliers positively, affecting the partnership agreements with suppliers. Moreover, a preferred supplier list can be established to be used in supply chain planning and execution in relation to obsolescence management, facilitating the procurement process.

The OM framework requires the establishment of an Obsolescence Management Team. This team must be cross functional. It must involve representatives from design, manufacturing and planning, supply chain, safety and reliability, business analysts, data scientists, and finance.

### 6.3 Limitations of the Obsolescence Management Framework

The implementation of this framework requires top management acceptance and support. Formal company policies and procedures related to the extension of PLM, the establishment and use of the CPPL, the flow of processes within the Shell Structure need to be developed and approved. Visible top management support will enforce the new policies and procedures and potentially reduce resistance to change.

The quality of data is of paramount importance for the success of this framework. Therefore, the consolidation of existing component libraries, the creation of the CPPL must be conducted with great care. The data collected from internal systems of the company (such as ERP, ECDTLs) must be analyzed carefully to determine the usage frequency of electronic components when establishing the CPPL. Also, the CPPL must be user-friendly to facilitate its adoption and reduce resistance to change.

New software tools are required for CEP and the CPPL. CEP software is available commercially, but must be integrated with the company's existing systems. For the CPPL, the required software can be developed in-house, as the company has the required expertise. Budget allocation for these must be undertaken by top management.

Access authorizations to obsolescence information must be formally controlled for the OM framework: which process owners can input data and under which circumstances, who can update the data and information, who can only receive information must be determined. Similarly, the recipients of CEP alerts (i.e. event consumers) must be defined carefully. Any omissions will jeopardize the integration sought by the framework.

The establishment of an OM unit and its place on the organization chart must be decided. One option would be to place this unit as part of the R&D Department, since the processes in the design phases are the most affected by obsolescence. Further, the job definitions of members of the OMT must be prepared.

The proposed OM Framework brings change in the way OM related processes are carried out. This change process must be carefully managed in order to cope with the resistance. A change agent preferably from the OMT can be appointed by top management during the transition to the OM Framework. Top management support is the essential to deal with resistance to change.

### 6.4 Recommendations for Future Work

Obsolescence cost drivers are an important element for the company when selecting obsolescence management strategies. Future research can focus on developing models that enable the determination of the most cost effective obsolescence management strategies.

Another area for future research involves the determination of CEP algorithms that create contextual data used to alert process owners about the obsolescence issues of electronic components.

As mentioned in Chapter 3, the UK and US have national standards covering the management of obsolescence in the defense industry. These standards facilitate and describe obsolescence management for defense companies. In this study the OM Framework is based on the CADMID lifecycle put forth by the UK Ministry of Defense standards (2006). But the framework is specific to the workflow of a particular company, and as such covers the company level. In Turkey, there are no national standards to guide other defense companies for the resolution of obsolescence issues. It would be beneficial to carry out research to form standards at a national level.

# REFERENCES

British Standards, European Standard. (2007). Obsolescence Management – Application Guide (BS EN 62402:2007). Retrieved from https://doi.org/10.3403/30123956 (published 31/08/2007)

Herald, T., Verma, D., Lubert, C., & Cloutier, R. (2009). An obsolescence management framework for system baseline evolution—Perspectives through the system life cycle. Systems Engineering, 12(1), 1-20.

IHS | Parts Intelligence. (2019). Retrieved November 24, 2019, from https://ihsmarkit.com/products/parts-intelligence-electronic-component-research.html.

JSP 886, The Defence Logistics Support Chain Manual, Vol 7 - Integrated Logistics Support, Part 8.13 - Obsolescence Management (JSP 886, 2012). UK Ministry of Defence policy. Available online at http://www.mod.uk/DefenceInternet/MicroSite/DES/OurPublications/JSP886/ (last accessed on 8th January 2015)

Kidd, M., & Sullivan, M. (2010). Reactive Obsolescence Management Measurements, a Better Approach. Naval Engineers Journal, 122(1), 75-80.

Leavitt, N. (2009). Complex-event processing poised for growth. Computer, (4), 17-20.

Luckham, D. C., & Frasca, B. (1998). Complex event processing in distributed systems. Computer Systems Laboratory Technical Report CSL-TR-98-754. Stanford University, Stanford, 28, 16.

Marshall, M. M., & Lambert, K. R. (2008, July). Insights into supporting complex systems under conditions of obsolescence. In Management of Engineering & Technology, 2008. PICMET 2008. Portland International Conference on (pp. 1918-1923). IEEE.

Meng, X., Thörnberg, B., & Olsson, L. (2014). Strategic proactive obsolescence management model. IEEE Transactions on Components, Packaging and Manufacturing Technology, 4(6), 1099-1108.

Meng, X., Thörnberg, B., & Olsson, L. (2012, September). Component obsolescence management model for long life cycle embedded system. In AUTOTESTCON, 2012 IEEE (pp. 19-24). IEEE.

Meyer, A., Pretorius, L., & Pretorius, J. H. C. (2004, October). A model using an obsolescence mitigation timeline for managing component obsolescence of complex or long life systems. In Engineering Management Conference, 2004. Proceedings. 2004 IEEE International (Vol. 3, pp. 1310-1313). IEEE.

Pobiak, T. G., Mazzuchi, T. A., & Sarkani, S. (2014). Creating a proactive obsolescence management system framework through the systems engineering continuum. Systems Engineering, 17(2), 125-139.

Rojo, F. J. R. (2011). Development of a Framework for Obsolescence Resolution Cost Estimation (Doctoral dissertation). Retrieved from https://core.ac.uk › download › pdf.

Rojo, F. J. R., Roy, R., & Kelly, S. (2012). Obsolescence risk assessment process best practice. In Journal of Physics: Conference Series (Vol. 364, No. 1, p. 012095). IOP Publishing.

Rojo, F. J. R., Roy, R., & Shehab, E. (2010). Obsolescence management for long-life contracts: state of the art and future trends. The International Journal of Advanced Manufacturing Technology, 49(9-12), 1235-1250.

Sandborn, P. (2013). Design for obsolescence risk management. Procedia CIRP, 11, 15-22.

Sandborn, P., Prabhakar, V., & Ahmad, O. (2011). Forecasting electronic part procurement lifetimes to enable the management of DMSMS obsolescence. Microelectronics Reliability, 51(2), 392-399.

Sandborn, “Trapped on technology’s trailing edge,” IEEE Spectrum, vol. 45, no. 4, pp. 42–58, Apr. 2008.

SAP. (2019). Event Stream Processor. Retrieved Dec 22, 2019, from https://www.sap.com/products/complex-event-processing.html.

SiliconExpert | Electronic Components Database. (2019). Retrieved November 24, 2019, from https://www.siliconexpert.com/.

Song, J. S., & Zipkin, P. H. (1996). Managing inventory with the prospect of obsolescence. Operations Research, 44(1), 215-222.

Top 20 Free, Open Source and Premium Stream Analytics Platforms - Compare Reviews, Features, Pricing in 2019. (2019, October 28). Retrieved December 2, 2019, from https://www.predictiveanalyticstoday.com/top-open-source-commercial-stream-analytics-platforms/.

Torresen, J. and Lovland, T. A. (2007). Parts Obsolescence Challenges for the Electronics Industry. Design and Diagnostics of Electronic Circuits and Systems, 2007. DDECS'07. IEEE, 11-13 April, pp. 1-4.

# APPENDICES

## A: TURKISH SUMMARY / TÜRKÇE ÖZET

### BİR SAVUNMA SANAYİ ŞİRKETİ İÇİN TEMİNSİZLİK YÖNETİM MODELİ

Bu tez, büyük ölçekli bir savunma sanayi şirketinde, elektronik malzemelerin teminsizlik yönetimi (TY) ile ilgili süreçlerinin analizini sunmaktadır. Bu süreçler şunlardır: Proje Yönetimi, Araştırma ve Geliştirme, Üretim ve Hizmetler ve Tedarik Zinciri Yönetimi. Bu çalışma, mevcut teminsizlik problemleri ve şirketin bunları çözmek için reaktif yaklaşımı açıklamaktadır. Elektronik malzemelerde teminsizlik sorunlarını azaltmak ve çözmek için yeni bir teminsizlik yönetim modeli şirket için önerilmiştir. Model, ürünlerin yaşam döngüsü boyunca, teminsizliğin olumsuz etkilerinin azaltılmasını ve dahası mevcut süreçlerde iletişim ve entegrasyon eksikliklerinin giderilmesini hedeflemektedir. Bu model; "Ürün Yaşam Döngüsü Yönetimi" kapsamının genişletilmesini, şirket genelinde "Tercih Edilen Parça Listesinin oluşturulmasını" ve mevcut elektronik malzeme kütüphanelerinin standartlaştırılmasını, teminsizlik yönetimi için "Karmaşık Olay İşleme"nin başlatılmasını ve yeni bir teminsizlik yönetimi sürecinin, şirketin teminsiz elektronik malzemelerle ilgili tüm süreçlerini birleştiren bir "kabuk yapısı" içinde kurulmasını önerir.

Teminsizlik, elektronik malzemelerin ürün yaşam döngülerinin sona ermesi nedeniyle orijinal üreticilerinde bulunamamasıdır (Sandborn, 2012). Elektronik malzemeler savunma sanayi şirketlerinin ürünlerini oluşturan en küçük birimler oldukları için, elektronik malzemelerin teminsizliği, orijinal malzeme üreticileri tarafından üretilmedikleri veya elektronik malzeme pazarında bulunamadıklarında, teminsizlik yönetimi (TY) sorunları yaratır. Elektronik malzemelerin bulunamaması, sistemleri üretirken ve sürdürürken teminsizlik sorunları yaratır. Tasarım, üretim, planlanan destek ömrü ve sistemlerin öngörülemeyen ömür uzatmaları savunma sanayinde uzun bir süreci kapsadığından, elektronik malzemelerin piyasadan teminsizliği genellikle kaçınılmazdır. “Teminsiz” terimi aynı zamanda “Üretim Kaynaklarının ve Malzeme Kıtlığının Azaltılması” olarak da bilinir (ÜKMKA- bu kısaltma ABD'de teminsizlik anlamına gelir) (Rojo, 2011).

Savunma sanayi ürünleri 20 ila 30 yıl arasında değişen, ürünlerin konsept fazından saha hayatlarının bitimine kadar uzun bir ürün yaşam döngüsü süresini kapsar. Savunma sanayi projelerinin kapsamı geniş, karmaşık ve oldukça maliyetlidir. Bu nedenle, sıklıkla, birbirleriyle ilişkili birkaç projeyi kapsayan “mega projeler” veya programlar olarak da adlandırılırlar. Ayrıca, bu ürünlerin geliştirilmesi çok yıllık projeler olduğundan, teminsizlik sorunları yalnızca ürünlerin saha içi yaşamı sırasında değil, aynı zamanda özellikle elektronik malzemelerin teminsizlikleri açısından da ürün geliştirmeleri sırasında da ortaya çıkmaktadır. Bu nedenle, şirketlerin ve kurumların (savunma sanayi bakanlıkları gibi) bu karmaşık sistemlerde ortaya çıkan teminsizlik sorunlarını yönetmek için sistematik bir yaklaşımı olmalıdır (Pobiak, Mazzuchi ve Sarkani, 2014).

Yeni elektronik malzeme teknolojileri ortaya çıktıkça ve bu malzemeler özellikle uzun ürün yaşam döngülerine sahip daha karmaşık sistemlerde kullanıldıkça, konsept fazlarından başlayarak, savunma sanayi ürünlerinde kullanılan malzemeler üzerinde sürekli teknik gözetimin yapılması ve sürdürülmesi zorunlu hale gelmektedir. Tasarım aşaması ve bu tür ürün geliştirmelerinde malzemelerin teminsizliğinin projeler üzerindeki etkilerini ve risklerini öngörmek, ürünün sahadan kaldırılmasına kadar izlenmesi gereken bir süreçtir.

Teknolojideki hızlı yenilik ve değişimlere ek olarak; elektronik malzemelerde bulunan ve Tehlikeli Maddelerin Kısıtlanması (TMK) uygunluk standartları ve gereklilikleri olarak da adlandırılan, belirli tehlikeli maddelerin kullanımına ilişkin, çevre, sağlık ve güvenlik kısıtlamalarını içeren düzenlemeler bulunmaktadır. Bu standartlar elektronik malzemelerde, teminsizlik problemleri ile sonuçlanan ve teminsiz malzeme yerine yeni bir alternatif malzeme değişikliği ihtiyacını daha da hızlandırır.

Ayrıca, elektronik malzemeler için uzun tedarik süreleri, tedarik zinciri faaliyetlerinde uzun süreli proje gecikmelerine neden olur. Elektronik malzemelerde TMK uygulamaları ile meydana gelen teminsizlik durumlarında; malzemeler tedarikçiden sipariş edildiğinde aktif bir durumda olsalar bile, tedarik zinciri faaliyeti bitmeden teminsiz duruma geçebilirler. Bununla birlikte, elektronik malzeme üretici şirketlerinin birleşme veya birbirlerini devralmaları, elektronik malzemelerin yaşam döngülerini kısaltarak savunma sanayi şirketleri için tedarik zinciri süreçlerini doğrudan etkilemektedir. Sonuç olarak teminsizlik problemleri yaratırlar. Bu nedenlerle, savunma sanayi projeleri teminsiz elektronik malzeme problemlerine karşı savunmasızdır. Bu durum da, şirkete uygun teminsizlik yönetimi faaliyetlerinin yokluğunda ciddi proje gecikmelerine ve finansal kayıplara neden olur. Etkili teminsizlik yönetimi yetenekleri ile donatılmış olan şirketler, bir ürünün yaşam döngüsünün başlangıcından sonuna kadar potansiyel elektronik malzeme teminsizlik tehditlerini öngörebilir ve proaktif ve / veya reaktif stratejiler, azaltma ve çözüm yaklaşımlarıyla teminsizlik durumlarına karşı stratejiler geliştirebilirler. Bu şekilde savunma sanayi şirketleri, elektronik malzemelerde teminsizlik risklerini ve proje yönetimi, araştırma ve geliştirme (Ar-Ge), üretim ve hizmetler ve tedarik zinciri yönetimi sırasında karşılaşılan bu riskleri en aza indirebildikleri kadar, projelerde gecikmeleri ve dolayısıyla proje gecikme cezalarını da en aza indirebilirler.

Savunma sistemlerinin konsept tasarım aşaması olan bir ürünün yaşam döngüsünün başlangıcından itibaren elektronik malzemelerin teminsizliği dikkate alınmalıdır. Elektronik malzemelerin teminsizliği, bu sistemlerin saha içi ömrü boyunca müşterilerle yapılan garanti ve bakım sözleşmelerine ilişkin önemli bir konudur. Savunma sistemlerinin yaşam döngüsü boyunca teminsizlik yönetimi, sistemlerin ve projelerin sürdürülebilirliğini ve ilgili maliyetlerini etkileyen kritik öneme sahiptir.

Savunma sanayiindeki şirketler için teminsizlik yönetimi Kritik Başarı Faktörlerinden biridir. Savunma sanayiindeki öncü ve en iyi şirketler teminszlik yönetimine büyük yatırımlar yapmakta ve bu konuya büyük önem vermektedir. ABD ve İngiltere savunma bakanlıkları, IEC 62402: 2007 ve BS EN 62402: 2007 (IEC 62402: 2007) gibi uluslararası standartları geliştirerek, uyarlayarak ve uygulayarak bu konuyu vurgulamaktadır ve her sene büyük ölçüde bütçe ayırmaktadırlar. BS, 62402: 2007). Savunma endüstrisinde British Aerospace ve Marconi Electronic Systems, Thales Aerospace, Selex Galileo gibi birçok önde gelen şirketin TY ile ilgili faaliyetleri vardır. Ayrıca, İngiltere Savunma Bakanlığı Ekipman ve Destek Bakanlığı, Ortak Teminsizlik Yönetimi Çalışma Grubu, Amerika Birleşik Devletleri Savunma Bakanlığı Savunma Lojistik Ajansı, Deniz Sistemleri Komutanlığı ve Havacılık Kurumu gibi teminsizlik yönetimi üzerinde çalışan çeşitli kuruluşları bulunmaktadır.

(Rojo, 2011). Teminsizlik yönetimine yapılan yatırımlar, projelerin maliyetini ve zaman etkililiğini doğrudan etkiler, bu da savunma sistemleri için teklif verirken rekabet avantajı sağlamaktadır.

Bu tezin amacı, büyük ölçekli bir savunma sanayi şirketinde, elektronik malzemelerin teminsizlik risklerini azaltmak ve yönetmek için bir teminsizlik yönetimi modeli önermektir.

Bu çalışmada önerilen model, ürünlerin yaşam döngüsü boyunca elektronik malzeme teminsizliklerinin olumsuz etkilerinin azaltılmasının yanı sıra şirketin mevcut teminsizlik ile ilgili süreçlerindeki iletişim ve entegrasyon eksikliklerinin giderilmesini de hedeflemektedir. Önerilen modelin unsurları, şirketin teminsizlik sorunları ile başa çıkmak için proaktif ve / veya reaktif stratejiler, azaltma ve çözümleme yaklaşımları benimsemesini sağlayacaktır.

Modelin odak noktası şirketin elektronik malzeme teminsizlik yönetimi ile ilgili süreçleridir: proje yönetimi, araştırma ve geliştirme, üretim ve hizmetler ve tedarik zinciri yönetimi.

Elektronik malzemeler teminsizlik tehdidi altındaki en büyük kalem grubunu oluşturmaktadır. Şirkette yaklaşık 12.000 farklı türde elektronik malzeme bulunmaktadır.

Elektronik malzemeler, birden fazla projede kullanılan, şirketin sistemlerinin, takımlarının ve elektronik kartlarının yapı taşları olarak düşünülebilir. Bu nedenle, elektronik malzemelerin teminsizlik yönetimi sistemlerin yaşam döngülerinin konsept tasarım aşamasında başlamalıdır. Teminsizlik yönetim süreçleri, proje yönetimi, araştırma ve geliştirme, üretim ve hizmetler ve tedarik zinciri yönetimi gibi diğer süreçlerle bütünleştirilmelidir. Tespit edilememiş teminsiz malzeme problemlerinde; özellikle proje yaşam döngülerinin ilk aşamalarında, çözüm yaklaşımlarını veya teminsizliğin olumsuz etkilerini azaltma stratejileri zamanında uygulanmadığında projeler için zaman ve maliyet başarısızlıklarına yol açar. Böylece elektronik malzemelerin teminsizliği tek bir projede bile milyonlarca dolara ulaşan parasal kayıplara yol açabilecek bir kartopu etkisi yaratır. Daha da önemlisi, teminsizlik sorunlarını sadece reaktif olarak çözmeye çalışmak geri dönüşü olmayan zaman kayıpları için açık bir davettir. Bu nedenle, şirket her projeyi teminsizlik yönetimi perspektifinden yönetmelidir.

Bu tezde önerilen model, "Ürün Yaşam Döngüsü Yönetimi" kapsamının genişletilmesini, şirket genelinde "Tercih Edilen Parça Listesi"nin oluşturulmasını ve mevcut elektronik malzeme kütüphanelerinin standartlaştırılmasını, teminsizlik yönetimi için "Karmaşık Olay İşleme"nin başlatılmasını ve yeni bir teminsizlik yönetimi sürecinin şirketin teminsizlikle ilgili tüm süreçlerini birleştiren bir "kabuk yapısı" içinde kurulmasını önerir. Bu model şirket içindeki teminsizlik yönetimi ile ilgili tüm süreçleri birleştirir. Bu modelin yukarıda belirtilen unsurları, şirketin TY faaliyetlerini bütünleştirerek ve teminsizlik problemlerini çözmek için teminsizlik yönetim stratejilerini geliştirmesini sağlar.

Savunma endüstrisindeki ürünler genellikle karmaşık sistemlerdir, ayrıntılı ve karmaşık iş süreçleri ile de korunurlar. Bu süreçler boyunca teminsiz elektronik malzemeler, projelerin yaşam döngüsü fazlarının aşamalarında konsept tasarımından ürünün saha içi aşamasına, saha hayatı yaşamından da imhasına kadar "saatin mekanik bir şekilde tıkır tıkır çalışması" gibi yönetilmelidir. Şirkette Ürün Yaşam Döngüsü Yönetimi (ÜYDY) kapsamının genişletilmesiyle, her bir sürecin kayıtlarının tutulmasının yanı sıra, her projede proje ekip elemanlarının rolünün ve yaptıkları işlerin ve iş akışlarının kayıtlı tutulması da mümkündür. Daha önce sadece tasarım süreçlerinde kullanılan Ürün Yaşam Döngüsü Yönetimi aracının, şirketin tüm süreçlerine genişletilmesiyle entegrasyon ve izlenebilirlik gerçekleştirilmektedir.

Şirket genelinde "Tercih Edilen Parça Listesi'nin" kurulması ve mevcut elektronik malzeme kütüphanelerinin standartlaştırılması, şirketin mevcut elektronik malzeme kütüphanelerindeki (Elektronik Kart Tasarım Araç Kütüphaneleri ve ERP) yinelemeleri ve bilgi girişi fazlalıklarını ortadan kaldırır. Şirketin "Tercih Edilen Parça Listesi'nin" (ŞTEPL) eksikliği, teminsizlik tehdidi altındaki malzemelerin doğru tespit edilememesine yol açmaktadır. Şirketin "Tercih Edilen Parça Listesi", herhangi bir malzeme ile ilgili tüm geçmiş verilere sahiptir ve alternatif malzemeler hakkındaki bilgilere erişilmesini sağlar. Yeni bir şirketin "Tercih Edilen Parça Listesi" veri tabanı yönetimi sistemi aracı entegrasyonuna sahip bir malzeme için, bir alternatif belirlendikten sonra, malzemeyi kullanan tasarımcılar, diğer tasarımcılar tarafından belirtilen alternatifler hakkındaki bilgilere erişebilir ve uygulanabilir bir alternatif için uzun süren bir aramada harcanacak değerli zamandan tasarruf edebilirler. Bununla birlikte şirketin "Tercih Edilen Parça Listesi", süreç sahiplerinin elektronik bir malzemenin herhangi bir modifikasyonuna veya teminsizlik veya piyasadan çekilme bildirimine hızlı bir şekilde yanıt vermesine izin verir.

"Ürün Yaşam Döngüsü Yönetimi" kapsamının genişletilmesi ve şirket genelinde "Tercih Edilen Parça Listesi'nin" kurulması projelerin daha verimli bir şekilde yönetilmesine ve takip edilmesine olanak sağlar. Örneğin, sözleşme gereklilikleri, gelecekteki teminsizlik sorunlarını gösteren elektronik malzemelerin yaşam döngüsü aşamalarının bilgisi ışığında daha kesin olarak belirlenebilir. Ayrıca bu, bakım ve servis sözleşmesi maddelerini ve müşteriye verilen hizmetlerin maliyetini de etkileyecektir. Bu maliyetlerin daha iyi belirlenmesi, şirket yeni projeler için teklif verirken avantaj kazanmasına yol açacaktır.

Karmaşık Olay İşleme (KOİ), proje yönetimi, araştırma ve geliştirme, üretim ve hizmetler, tedarik zinciri yönetimi ve teminsizlik yönetimindeki süreç sahiplerinin elektronik malzemelerin durumu hakkında uyarılmasını sağlar. Karmaşık olay işlemedeki algoritmalar, elektronik kartların üretim analizi, sistem mühendisliği ve güvenlik ve güvenilirlik analizi de dahil olmak üzere şirketin ERP, ÜYDY, ŞTEPL ve BOM Teminsizlik Yönetimi aracındaki verileri kullanır. İlgili süreç sahiplerini uyarmak için gösterge tabloları ve teminsiz malzeme bildirimleri oluşturulur; bunlar daha sonra teminsizliğin etkilerini azaltmak için TY stratejileri geliştirebilir.

Önerilen yeni Kabuk Yapısı, ürünlerde kullanılan elektronik malzemeleri teminsizlik durumlarına karşı, midyenin incisini kabuğunun içerisinde dış zararlı etkilerden koruduğu gibi bir koruma yapısı olarak düşünülebilir. Ürünün yaşam döngüsü ne fazda olursa olsun, elektronik malzemeler bu Kabuk Yapısı ile sürekli olarak izlenir, potansiyel teminsizlik riskleri belirlenir ve şirket teminsizlik risklerini öngörüp bunları proje planlama tarihlerine göre yönetebildiğinden gelecekteki proje zaman ve maliyet kayıpları en aza indirilir.

Bölüm 4,3 'teki şirkette meydana gelen teminsizlik yönetimi örneğinde belirtildiği gibi, teminsizlik sorunları bir yıl boyunca şirket içerisinde çözümsüz kalabilmekteydi ve geri dönüşü olmayan proje planlama gecikmelerine ve proje toplam maliyet artışlarına yol açabilmekteydi. Önerilen yeni teminsizlik yönetim modeli, teminsizlik sorunlarının gerçek zamanlı olarak tespitini ve tespit edilen sorunların otomatik olarak ilgili süreç sahipleriyle paylaşılmasını sağlamaktadır.

Şirketin var olan süreçlerinde, teminsizlik sorunları hakkında herhangi bir süreç teminsiz malzeme bildirimi aldıktan sonra bile, hangi elektronik kartların teminsiz malzemeyi kullandığını belirlemek ve bu malzemeyi projelerinde kullanan tüm tasarımcıları bilgilendirmek haftalar sürmekteydi. Yeni modelde, örneğin, 80 elektronik karttan 30 elektronik kart için alternatif bir malzeme değişikliği gerekiyorsa, bu sorun derhal karmaşık olay işlemeleri (KOİ) aracılığıyla ilgili süreç sahiplerine aktarılmaktadır. Bölüm 4'te belirtildiği gibi, hangi elektronik karttan kimin sorumlu olduğunun araştırılması ve ilgili işlem sahibine teminsiz malzeme ile ilgili durum bildiriminin ulaştırılması artık yeni model ile haftalar yerine saniyeler içerisinde süreç sahiplerine iletilecektir. Ayrıca, şirketin "Tercih Edilen Parça Listesi'nde" zaten alternatif bir malzeme tanımlanmışsa, doğrudan kullanılabilir durumda olabilecektir. Başka bir deyişle, haftalar veya günler için uygun bir alternatif malzeme aramak yerine, onaylanan ve şirketin "Tercih Edilen Parça Listesi'ne" dahil edilen alternatif bir malzeme kullanılabilir. Bu, uygun bir alternatif araştırmasının haftalardan günlere indirildiği anlamına gelir.

Şu anda, malzemeyi kullanarak tüm tasarımcılara malzemelerin teminsizlik bilgilerini göndermek sıralı adımlardan oluşmaktadır. İlk olarak teminsizlik bilgileri şirketin ERP aracından elde edilir ve ilgili tüm süreç sahipleri belirlenir. Ardından, teminsizlik uyarısı ilgili işlem sahiplerine e-posta yoluyla iletilir. Karmaşık olay işleme sistemi ile de teminsizlik uyarıları gerçek zamanlı ve otomatik olarak ilgili süreç sahiplerine gönderilebilir.

Günümüzde teminsizlik sorunları teknolojinin çok hızlı gelişmesi ve Bölüm 3'te bahsedilen diğer teminsizliğe neden olan ana nedenlerden dolayı sıklıkla gerçekleşmektedir. Yeni teminsizlik yönetim modeli ile şirketin yaklaşık 12.000 elektronik malzemesinden her birini projeleri içerisinde takip etmesi ve teminsizlik riski altındaki kritik malzemelerini sürekli proje planları içerisinde gözlemlemesi artık mümkündür. Bu şekilde, teminsizliğin projelerin zaman ve maliyet çizgileri üzerindeki olumsuz etkilerini önemli ölçüde azaltarak, proaktif teminsizlik yönetimi stratejileri projenin tüm malzemeleri için kurulabilir. Böyle bir izlemenin aynı zamanda, zaman alıcı ve maliyetli bir etkinlik olan tasarım yenileme ihtiyacını da azaltması kuvvetle muhtemeldir.

Yeniden tasarım, eski malzemelerin yenisiyle değiştirilirken sistemi de geliştirmeye ve yenilemeye dayanır. Yeniden tasarımın amacı, sistemlerin veya kartın performansını, sürdürülebilirliğini ve güvenilirliğini iyileştirmenin yanı sıra yeni malzemelerin kullanılmasını sağlamaktır. Yeniden yeterlilik / yeniden sertifikalandırma gereklilikleri nedeniyle bu çözüm en pahalı çözümdür. Bu nedenle, bu uzun vadeli çözüm son çare olarak kullanılmalıdır. Ayrıca elektronik sistemlerdeki işlevsellik yükseltmeleri (teknoloji ekleme) gerektiğinde kullanılmalıdır (Rojo, 2011). Eski malzemeyi yeniden tasarlama ile alternatifiyle değiştirmek, diğer çözüm yaklaşımlarına kıyasla uzun zaman ve yüksek maliyet gerektirir.

Envanterdeki eski malzemelerin analizi ve değerlendirilmesi, şirketin süreçlerindeki elektronik malzemelerin projelerde kullanım verilerine ve şirketin Malzeme Kaynak Planlama (MKP) verilerine dayanmaktadır. Hangi teminsizlik yönetim stratejisinin uygulanması gerektiğine karar vermek için, envanter, stok kontrolü bir şirketin finansal kaynak yönetiminde önemli bir rol oynar. Envanteri etkileyebilecek malzemelerin envanterdeki durumları ile ilgili her şey dikkatle izlenmelidir. Malzemelerin orijinal üreticileri tarafından artık üretilmeyip piyasadan temin edilememe olasılığı ve maliyet üzerindeki etkisi sadece malzemenin tahmini teminsizlik süresini belirlemekle kalmaz, aynı zamanda envanteri daha kontrollü bir şekilde yönetir. Hangi teminsizlik yönetim stratejisinin uygulanacağının belirlenmesine yol açar. Teminsizlik ile ilgili stok kontrolü önemlidir. Bununla birlikte, bu konu ile ilgili Song & Zipkin (1996) şunları söylemiştir: "Geleneksel envanter kontrol yöntemleri olası teminsizlik yönetim kontrollerine izin vermiyor." Geleneksel envanter izleme ve yönetim yöntemlerinin, teminsiz malzemelerin getirdiği zorluklara uyum sağlanması için yetersiz kaldığı doğrudur. Verimli stok kontrolü yapabilmek için malzemelerin teminsizlik tarihlerinin belirlenmesi gerekmektedir. Buna ek olarak, teminsizlik yönetiminde sadece malzemenin tahmini teminsizlik tarihini değil, aynı zamanda malzemeler hakkında yapılan çevresel düzenlemelerin etkilerini, ayrıca sistemi etkileyebilecek finansal riskleri, üretim programını ve elektronik malzeme piyasasında oluşan gelişmeler de kaçınılmaz bir şekilde teminsizliğe yol açmaktadır ( Herald ve ark.2009).

Envanter politikası, şirketlerin üretim ve tedarik zinciri yönetimi zorluklarıyla başa çıkmak için benimsediği Konsinye Stok (KS) envanter politikasıdır. Konsinye Stok politikası, alıcı ve tedarikçisi arasındaki işbirliğini ele almaktadır. Konsinye Stok politikası, bilgi alışverişini belirli prosedürlere uygun yapılarak ve taraflar arasındaki riskin paylaşımını sağlar. Bu politika kapsamında ürün teminsizlik etkisi tedarik zinciri maliyetleri açısından dikkatle değerlendirilir. Konsinye Stok, genel satış amaçları için envanteri artık saklamadığı halde tedarikçinin alıcı için envanter tutmaya devam ettiği anlamına gelir. Alıcı, satıcının ikmal ve envanter yönetimi sorumluluğunu üstlendiği malzemenin kullanılabilirliğini sürdürme avantajına sahiptir ve iki taraf arasındaki anlaşmalara göre toplam ortak maliyetleri ve stok risklerini azaltmayı mümkün kılar (Catena ve ark., 2014). Konsinye Stok politikası envanterdeki tüm malzemeler için geçerli değildir ve teminsizlik riskleri ve maliyet üzerindeki etkileri nedeniyle yüksek karmaşıklığa sahip malzemelere uygulanabilir. Kritik malzemeler için uygundur ve Bölüm 3.7.1.1'de açıklanan bir azaltma stratejisi olarak tedarikçilerle ortaklık anlaşması için düşünülebilir.

Teminsiz malzemeler için teminsizlik yönetim azaltma strateji seçenekleri belirlenirken, fazla envanter de değerlendirilmelidir. Ayrıca, teminsizliği azaltmak için yeniden tasarım seçeneği olduğunda, tedarikle ilgili seçeneklerin geçerli olmadığı durumlarda, teminsiz malzeme değiştirilirken stok verileri gerekir. Ayrıca, tasarımcılar için daha iyi bir malzeme seçimi sağlayan ve envanteri azaltan Tercih Edilen Parça Listesi'nin (PPL) standardizasyonu, dikkatli envanter yönetimine dayanmaktadır (Meyer ve diğerleri, 2004).

Tedarik zinciri azaltma stratejisi olarak, Yaşam Boyu Satın Alma (3.7.2.1'de tartışılmıştır) şirketin envanterini etkiler, çünkü eski parçaların ileri düzeyde depolanmasına yol açar. Hangi teminsizlik stratejisinin uygulanacağına karar vermek için teminsizlik maliyeti savunma sistemleri için önemlidir.

Bu model aynı zamanda şirketin taşeronları ve tedarikçileri ile olan ilişkisini de etkiler. Bu yeni model altında, teminsiz malzeme bilgileri proaktif olarak taşeronlarla paylaşılabilir, bunlar arasında şirketin çoklu veri kaynaklarından çıkarılan ve analiz edilen malzeme verilerinden önemli performans göstergeleri ölçülerek ve raporlanarak elde edilen kritik malzemeler hakkında bilgiler de bulunur. Bu, tedarikçilerle olan ortaklık anlaşmalarını etkileyerek tedarikçilerle olan ilişkileri olumlu yönde değiştirebilir. Ayrıca, malzemelerin tedarik sürecini kolaylaştırarak teminsizlik yönetimi ile ilgili olarak tedarik zinciri planlaması ve uygulamasında kullanılmak üzere tercih edilen bir tedarikçi listesi oluşturulabilir.

Teminsizlik yönetim modeli, bir Teminsizlik Yönetim Ekibinin kurulmasını gerektirir. Bu ekip şirket içerisinde süreçler arası çapraz işlevselliğe sahip olmalıdır. Tasarım, üretim ve planlama, tedarik zinciri, güvenlik ve güvenilirlik mühendisliği, iş analistleri, veri bilimcileri ve finans temsilcilerini içermelidir.

Bu modelin uygulanması üst yönetimin kabulünü ve desteğini gerektirir. "Ürün Yaşam Döngüsü Yönetimi" kapsamının genişletilmesini, şirketin "Tercih Edilen Parça Listesi" kurulması ve kullanılması, Kabuk Yapısı içindeki süreçlerin akışı ile ilgili resmi şirket politika ve prosedürlerinin geliştirilmesi ve onaylanmasını gerektirmektedir. Görünür üst yönetim desteği, yeni politikaları ve prosedürleri uygulayacak ve potansiyel olarak değişime karşı direnci azaltacaktır.

Verilerin kalitesi bu çerçevenin başarısı için büyük önem taşımaktadır. Bu nedenle, mevcut malzemelerin kütüphanelerinin konsolidasyonu, şirketin "Tercih Edilen Parça Listesi" oluşturulması işi büyük bir dikkatle yapılmalıdır. Şirketin "Tercih Edilen Parça Listesi" kurulurken elektronik malzemelerin kullanım sıklığını belirlemek için şirketin iç sistemlerinden (ERP, elektronik kart tasarım araçları kütüphaneleri gibi) toplanan veriler dikkatle analiz edilmelidir. Ayrıca, şirketin "Tercih Edilen Parça Listesi" benimsenmesini kolaylaştırmak ve değişime karşı direnci azaltmak için kullanıcı dostu olmalıdır.

Karmaşık olay işlemeleri (KOİ) ve şirketin "Tercih Edilen Parça Listesi" için yeni yazılım araçları gerekmektedir. Karmaşık olay işlemeleri yazılımı ticari olarak mevcuttur, ancak şirketin mevcut sistemleriyle entegre edilmelidir. Şirketin "Tercih Edilen Parça Listesi" için, şirket gerekli uzmanlığa sahip olduğundan, gerekli yazılım şirket içinde geliştirilebilir. Bunlar için bütçe tahsisi üst yönetim tarafından yapılmalıdır.

Elektronik malzemelerin teminsizlik bilgilerine erişim yetkileri TY modeli için resmi olarak kontrol edilmelidir: hangi süreç sahipleri veri girebilir ve hangi koşullar altında veri ve bilgileri güncelleyebilecek ve sadece bilgi alabilecek süreç sahipleri belirlenmelidir. Benzer şekilde, Karmaşık olay işlemeleri uyarılarının alıcıları (yani olay tüketicileri) dikkatle tanımlanmalıdır. Herhangi bir ihmal, model tarafından önerilen entegrasyonu tehlikeye atacaktır.

Bir teminsizlik yönetim biriminin kurulması ve organizasyon şemasındaki yeri kararlaştırılmalıdır. Seçeneklerden birisi, bu birimi Ar-Ge Departmanının bir parçası olarak AR-Ge süreçleri altına yerleştirmek olabilir, çünkü tasarım aşamalarındaki süreçler teminsizlikten en çok etkilenen süreçlerdir. Ayrıca, teminsizlik yönetim takımı üyelerinin iş tanımları hazırlanmalıdır.

Önerilen teminsizlik yönetim modeli, teminsizlik yönetimi ile ilgili süreçlerin gerçekleştirilme biçiminde değişiklik getirir. Şirket içi dirençlerle başa çıkmak için bu değişim süreci dikkatle yönetilmelidir. Değişime karşı dirençle başa çıkmak için üst yönetim desteği şarttır.

## B. THESIS PERMISSON FORM / TEZ FOTOKOPİSİ İZİN FORMU

**ENSTİTÜ /** INSTITUTE

**Fen Bilimleri Enstitüsü** / Graduate School of Natural and Applied Sciences ☐

**Sosyal Bilimler Enstitüsü** / Graduate School of Social Sciences ☒ x

**Uygulamalı Matematik Enstitüsü** / Graduate School of Applied Mathematics ☐

**Enformatik Enstitüsü** / Graduate School of Informatics ☐

**Deniz Bilimleri Enstitüsü** / Graduate School of Marine Sciences ☐

**YAZARIN /** AUTHOR

**Soyadı** / Surname :SAYGIN

**Adı** / Name :NİLÜFER

**Bölümü** / Department :BUSINESS ADMINISTRATION

**TEZİN ADI /** TITLE OF THE THESIS (**İngilizce** / English) :

AN OBSOLESCENCE MANAGEMENT FRAMEWORK FOR A DEFENSE INDUSTRY COMPANY

..........................................................................................................................................

..........................................................................................................................................

**TEZİN TÜRÜ /** DEGREE**:** **Yüksek Lisans** / Master x **Doktora** / PhD ☐

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. ☐

2. **Tez iki yıl süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **two years. *** ☐

3. **Tez altı ay süreyle erişime kapalı olacaktır.** /Secure the entire work for period of **six months**. ***** x

***** *Enstitü Yönetim Kurulu kararının basılı kopyası tezle birlikte kütüphaneye teslim edilecektir.*

*A copy of the decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.*

**Yazarın imzası** / Signature ............................ **Tarih** / Date ………………………