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Selection of obsolescence resolution strategy based on a multi criteria decision model

Pratik Pingle
Iowa State University

Selection of obsolescence resolution strategy based on a multi criteria decision model

by

Pratik Pingle

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Program of Study Committee:
Janis Terpenny, Major Professor
Sigurdur Olafsson
Suzuki Yoshinori

Iowa State University

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NOMENCLATURE

COTS	Commercial off the Shelf
PDCA	Plan-Do-Check-Act
PCN	Product Change Notification
BOM	Bill of Material
ORS	Obsolescence Resolution Strategy
MAUT	Multi Attribute Utility Theory
EEE	Electronic, Electrical and Electromechanical
DMSMS	Diminishing Manufacturing Sources and Material Shortages
MRI	Material Risk Indices
LTB	Life Time Buy
OMP	Obsolescence Management Plan
PCN	Product Change Notification
EOL	End of Life
FEA	Finite Element Analysis

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ABSTRACT

A component becomes obsolete when it is no longer available from its original manufacturer in its original form. Component obsolescence is a significant problem in the electronics industry. There are different strategies employed to address this problem, for example, using an alternative part, life time buy, redesign etc. Often, techniques used in industry select one of these options based on the most economical solution as determined by minimizing direct costs. However, there are factors other than cost, such as the number of suppliers, time constraints, reliability of the solution etc., which may play a crucial role in determining an overall best decision. In addition, there are multiple stakeholders like design, operations, manufacturing, sales, service etc., who might have different opinions when it comes to obsolescence management. This research provides a multi criteria decision model that will consider the trade-offs among multiple factors and provide the decision maker solution that will be acceptable to a wide variety of stakeholders as well as being viable from the company's perspective. The model is based on multi attribute utility theory. It will provide the stakeholders a platform to express their preferences and experience in the decision process. And, based on the overall utility value, the most suitable obsolescence resolution strategy for a specific application will be provided. The research provides a hypothetical case study in order to illustrate the application and usage of the model.

CHAPTER 1 : INTRODUCTION

1.1 Background

In the last few decades there has been an exponential growth in technology, resulting in the rapid introduction of new components with added functionality and features. This has led to increased pressure to replace and/or upgrade components and/or subsystems in manufactured products. In "high-tech" industries, such as space, avionics and defense, the life time of systems can extend over many decades. One of the major problems that these systems face during their lifetime is obsolescence [1]. Obsolescence for a part can be defined as a situation when the component is no longer available from stock or cannot be procured in its original form from its original manufacturer [1-5]. Obsolescence arises due to the mismatch between the life span of the product (the overall assembly) and the parts/components (individual parts or sub-assemblies that make a product).

Complex systems, such as aircrafts, submarines etc., take many years to design and manufacture and are typically maintained for decades. These systems are usually composed of "commercial off the shelf (COTS)" components, which are highly dependent on market trends and technological changes. COTS components frequently have shortened life cycles and experience obsolescence quickly [1]. The key characteristics of these sustainment-dominated systems are:

- Strict requalification requirements, which lead to high redesign costs, [6]
- Low production volumes, which lead to little or no control over the associated supply chain [4, 6, 7, 8], and
- Higher sustainment costs compared to original cost of the system [6].

QTEC estimates that approximately 3% of the global pool of electronic parts becomes obsolete every month [9]. For example, in 2013, over 350,000 components became obsolete, reflecting the magnitude of the problem industry is facing.

1.2 Motivation

The effect of obsolescence is high overall cost in maintaining long life systems. For instance, according to the US Navy estimations, obsolescence issues cost up to $750 million annually [11]. This makes obsolescence management a key decision for maintaining profitability in long life systems. Obsolescence management is defined as the "activities that are undertaken to mitigate the effects of obsolescence" [10]. Activities can include last-time buy, life-time buy, and obsolescence monitoring. To ensure that an obsolescence management plan improves continually Bartels *et al.* [10] proposed applying Plan-Do-Check-Act (PDCA) cycle to create an obsolescence management plan. Figure 1-1 (adapted from IEC-62402, 2004 and [10]) shows a process of managing obsolescence.

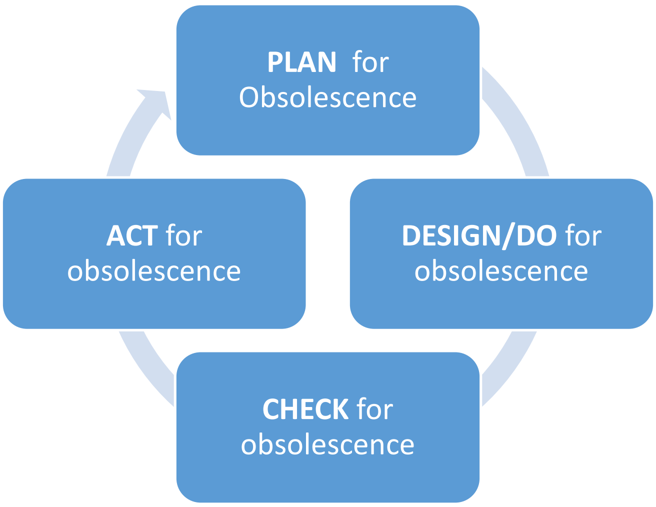

Figure 1-1 : Steps to manage obsolescence

There are three broad categories of obsolescence management strategies: reactive, proactive and strategic, as shown in Figure 1-2 [10, 14].

Figure 1-2 : Obsolescence management categories and the resulting outputs

Reactive management deals with the problem after the part has already become obsolete or after receiving the Product Change Notification (PCN) from the original part manufacturer. Some of the common reactive strategies are lifetime buy, bridge buy, buying parts from aftermarket sources, part replacement, emulation, and reclamation [14].

In proactive management, steps are taken prior to actual obsolescence of a part. This strategy is mainly used for critical parts that have high risk of becoming obsolete or if the availability of the component is low after the part becomes obsolete. Proactive management involves using forecasting methodology to predict obsolescence dates of various parts in a product, analyzing the risk of obsolescence of critical parts in a Bill of Material (BOM) and then taking necessary steps to manage obsolescence [14].

Strategic management is used for strategic planning, life cycle optimization, and long-term business case development for the support of systems. It uses the lifecycle information of various parts, logistics management inputs, technology forecasting, and business trends. Some of the common strategic resolution strategies are Material Risk Index (MRI) and Design Refresh Planning.

To date, most of the tools or approaches that are used to manage or mitigate obsolescence are based on cost optimization approaches. These tools are quantitative in nature and aim to minimize the overall cost of obsolescence management. One of the challenges in obsolescence management however, is that there are many factors, other than cost, that must be considered while choosing an "Obsolescence Resolution Strategy" (ORS). Some of these factors include consideration of the market demand of the product, functional performance of the solution, sustainability of the solution, and the time available for implementation of the solution. Further, there are multiple stakeholders in decision-making such as sales, purchasing, quality control, design, manufacturing, and more. Thus, choosing a suitable obsolescence resolution strategy depends on multiple quantitative factors as well as considerations that include qualitative factors. One of the most promising ways to account for quantitative and qualitative factors in a decision is to use a multi criteria decision model.

1.3 Objective and Research Questions

The primary objective of this research is to investigate the use of multi criteria decision model for obsolescence management. A decision model based on Multi Attribute Utility Theory (MAUT) will serve as the foundation for the research. This model will compare the utility values of various resolution strategies and propose a suitable obsolescence resolution strategy based on maximum utility value. MAUT is well suited for this work since it is a structured methodology designed to handle the trade-offs among multiple objectives. Further, since utility theory is a systematic approach for quantifying an individual's preferences, it will be used to rescale numerical values on measures of interest onto a 0-1 scale with 0 representing the worst preference and 1 the best. This will allow for the direct comparison of many diverse measures that are at the core of obsolescence management.

Several research questions associated with this work are provided below and are grouped in three categories: stakeholders, factors affecting decision making, and the decision model.

1.3.1 Stakeholders

Q1. Who are the key stakeholders that may have impact on decision making in obsolescence management?

Q2. How can the opinions of stakeholders be represented?

Q3. How does the opinion of various stakeholders affect obsolescence management plan?

1.3.2 Factors affecting decision making

Q1. What are the various factors that need to be considered while making a decision for obsolescence management?

Q2. What is the relevance of these factors in the decision making process?

1.3.3 Decision model

Q1. How to incorporate the quantitative and qualitative factors in the decision making process?

Q2. How to analyze the trade-offs between various factors that affect obsolescence management in the decision model?

1.4 Methodology and Approach

Figure 1-3 shows the key deliverables of this research. First, the background of current obsolescence management practices will be discussed. This includes various obsolescence management approaches and current models used to select a suitable obsolescence resolution strategy. Next, key stakeholders will be identified along with their role served in decision making. Then, factors affecting decision will be identified along with a discussion of trade-offs. Then, using MAUT a decision model will be developed. Finally a case study will be presented to elaborate, test, and validate the proposed decision model.

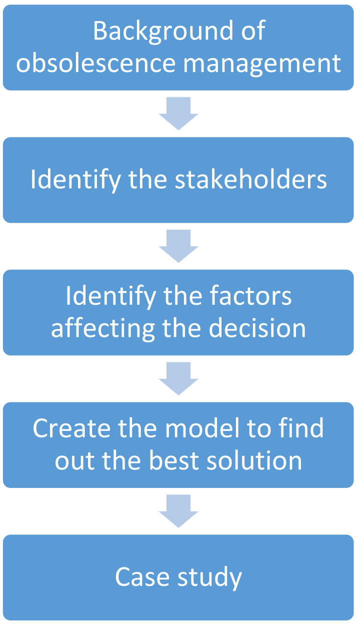

Figure 1-3 : Deliverables of thesis

1.5 Outline of Thesis

As shown in the Figure 1-4 after the first chapter i.e. introduction, the second chapter gives a literature review about product obsolescence. Chapter 3 presents the research methodology and results, chapter 4 presents a case study and chapter 5 summarizes the contribution and future scope of research.

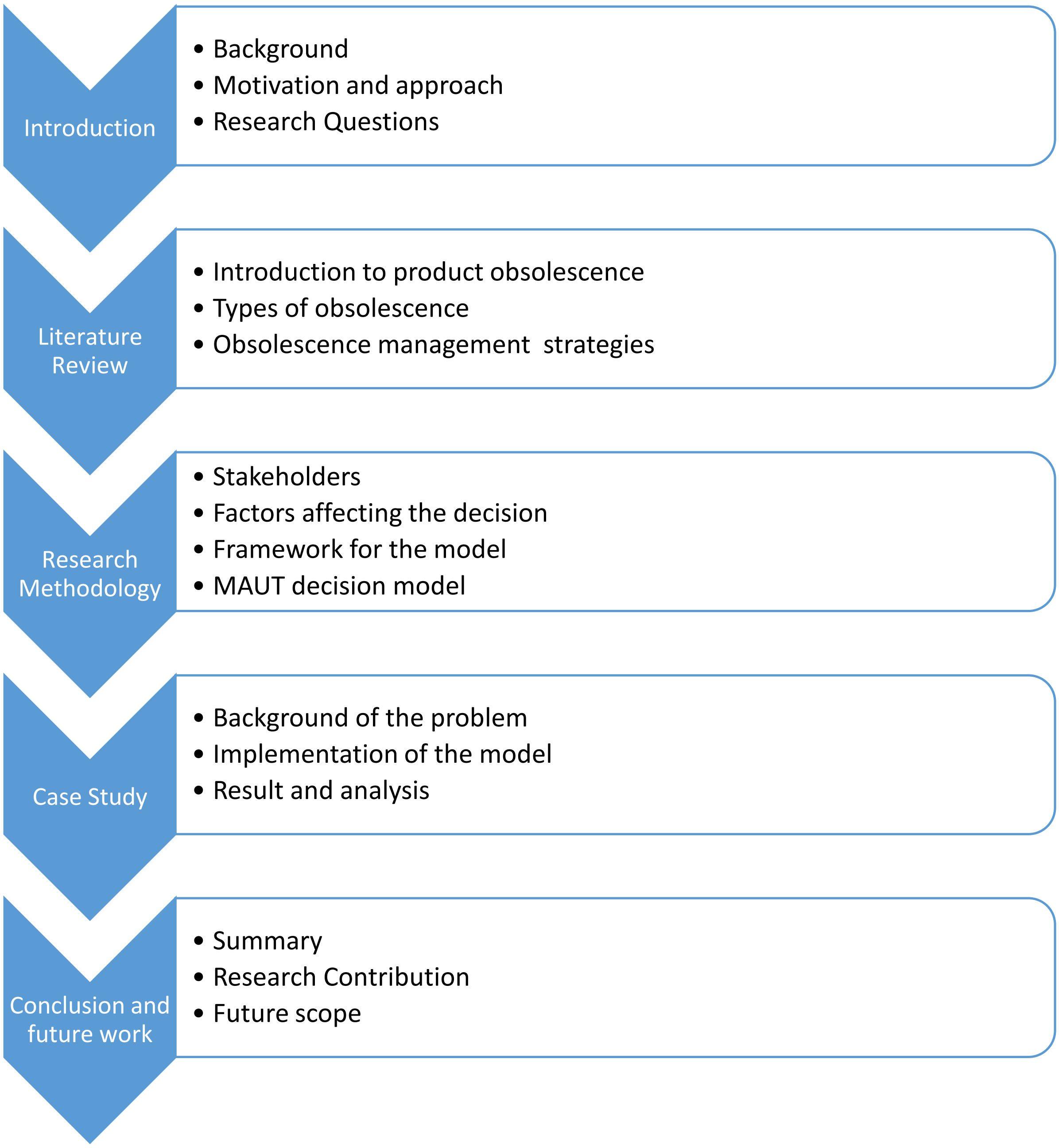

Figure 1-4 : Outline of thesis

CHAPTER 2 : LITERATURE REVIEW

This chapter summarizes the research done in the field of obsolescence and obsolescence management. A brief background to the problem of product obsolescence is provided as well as various reasons for obsolescence, areas in which this problem is prevalent, various obsolescence management strategies and current decision models for obsolescence management are presented. The chapter concludes with a summary of the current strategies and highlights the need for the proposed work based on the literature.

2.1 Introduction to Product Obsolescence

Obsolescence can be defined as the "loss or impending loss of original manufacturers of items or suppliers of items or raw materials" [28]. The primary reasons for obsolescence are market trends and technological changes. Obsolescence has become a major problem in long field life sustainment dominated systems, such as avionics, military and spacecraft. These systems are manufactured and maintained over decades. A classic example is the B-52 bomber (see Figure 2-1) [29], which was introduced in 1955, yet has a planned service life until 2040 . . . more than 80 years of service life! Due to higher demands in consumer electronic goods, manufacturers have stopped producing low-volume components for military purposes. The defense sector now employs COTS components, which are economically more viable. Unfortunately, COTS parts are dependent on market trends and may become obsolete in a very short span of time. In fact, many parts become obsolete during the design stage, even before the system is fielded. For example, in the surface ship sonar system, over 70% of the parts became obsolete before the system was even installed [12].

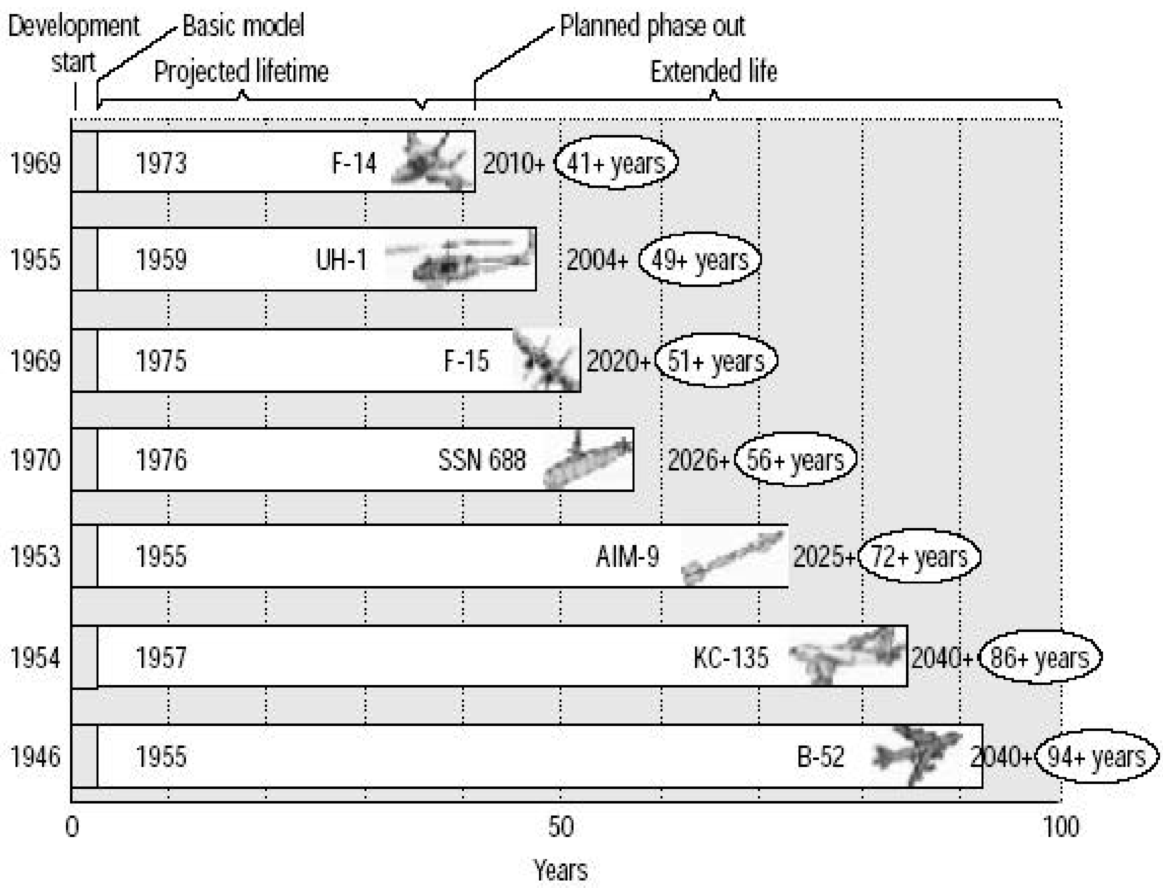

Figure 2-1 : Weapon system life cycles

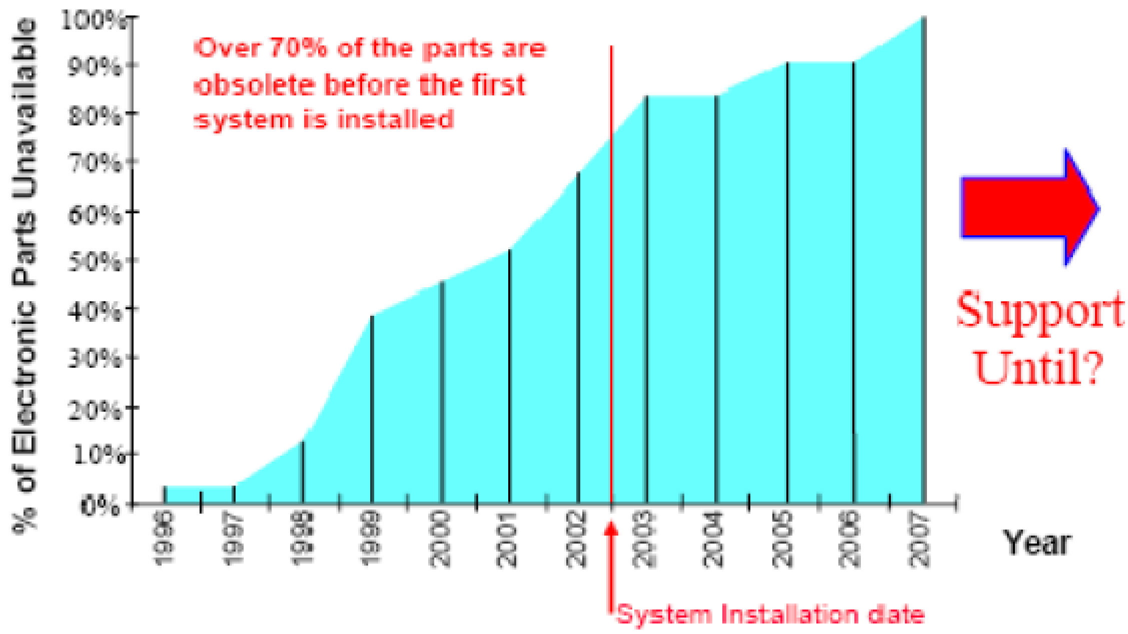

Figure 2-2 : Surface ship sonar system (NSWC Crane)

2.2 Causes of Obsolescence

There are four primary reasons for obsolescence that help to define the problem area, including: functionality improvement dominated obsolescence, logistical obsolescence, functional obsolescence, and technological obsolescence [26], each is described below.

2.2.1 Functionality Improvement Dominated Obsolescence (FIDO)

With market trends, customer demands and competition, manufacturers need to upgrade products to maintain market share, which causes existing products to become obsolete. This is an example of forced obsolescence, as manufacturers have to upgrade due to market pressure.

2.2.2 Logistical obsolescence

This is caused when a manufacturer cannot procure the parts, materials or software necessary to manufacture and/or support a product.

2.2.3 Functional obsolescence

A product may become obsolete even when the current design of the product can be manufactured or supported. This occurs when the specific requirements of the product have changed, which causes the current function, performance or reliability of the product to become obsolete.

2.2.4 Technological obsolescence

Due to the innovations in the technology, more advanced components become available. One may have the inventory of the older part and can still use it in a system. However, the supplier of the older part no longer supports it, causing the obsolescence of the part.

2.3 Areas of Product Obsolescence

It has been predicted that the issue of obsolescence is going to occur more often in the future due to the rapid rate of growth of technology rich innovations. The problem of product obsolescence is more prevalent in Electronic, Electrical and Electromechanical (EEE) components due to the shorter lifecycles of the components [3, 15, 16, 17]. However, it is not restricted only to EEE, there are other types of product / industries where obsolescence might occur. Figure 2-3 [13] shows the holistic view of obsolescence [13]. In non-electronic systems the rate of obsolescence is relatively slower than that in electronic systems where drastic shift in technology is not as common [13].

Figure 2-3 : Holistic view of obsolescence

2.3.1 Mechanical Components and Materials

In long life systems, mechanical parts break down more frequently and in unexpected ways, mainly due to aging of the parts [16]. As suppliers develop better parts using stronger and lighter materials that have better wear resistant properties, older materials and parts become obsolete and phase out for new production [13, 16]. The new materials may be better in many aspects, but there could be a mismatch between the old part and the new part, as the new part may not have the right mechanical or chemical properties to be a direct replacement for the older material. The absence of direct replacement may lead to redesign of the system [13]. Material may also become obsolete due to changes in environmental regulations such as the Restriction of Hazardous Substances Directive [18].

2.3.2 Processes and Procedures

One of the primary reasons for obsolescence in manufacturing processes is environmental regulations [16]. If a material becomes obsolete then it may cause the manufacturing process to become obsolete or if a manufacturing process becomes obsolete then the material may become obsolete. Therefore material obsolescence and manufacturing obsolescence are interrelated [13].

2.3.3 Software and Media:

In the last two decades the software industry has grown at a very high rate and software upgrades have become a frequent practice. One of the main reasons for software upgrades is the innovation in hardware. For example, benefits from improvements in computer hardware have enabled faster speeds, larger storage, etc. However, such improvements can lead to incompatibility of older versions of software with newer hardware, leading to software obsolescence. Software development firms, as a strategy, are no longer supporting older versions of software. For example, in 2014 Microsoft announced the end of support for Windows XP, which was launched in 2001. In complex systems the contribution of software lifecycle cost is almost the same, or sometimes more than the hardware lifecycle cost in the total lifecycle cost of the system [19].

2.3.4 Skills and knowledge

Skill obsolescence is the "degree to which professionals lack the up-to-date knowledge or skills necessary to maintain effective performance in their current or future work roles" [20]. The management of skills and knowledge is very important to retain the people with specific skillsets for the sustainment of long life systems [13]. The key to mitigate this form of obsolescence is to keep track of "skillsets" of employees and provide training necessary as required. If skills obsolescence is not tackled, it can drive obsolescence issues in other areas such as software.

2.3.5 Manufacturing tooling

The manufacturing aids required to fabricate components are regarded as 'tooling' (e.g. forging dies, holding fixtures, sheet metal patterns, casting moulds) [16]. Obsolete tooling may need to be refurbished or recreated, otherwise it may impact manufacturing processes. Likewise, a change in a manufacturing process driven by a change in material or form may cause tooling to become obsolete.

2.3.6 Test equipment

Test equipment becomes obsolete at the end of the production phase as it is no longer required [16]. However it may be necessary to test if a replacement for a component is form, fit, function, and interface compliant to tackle a component obsolescence issue.

Currently, few researchers [16, 21-24] have studied the obsolescence problem outside the electronics area. It is reported that 84% of the discontinued items are electronic components with the rest being mechanical and passive devices [25], however the impact of obsolescence in areas other than EEE should not be underestimated.

2.4 Obsolescence Management Strategies

There are three types of obsolescence resolution strategies, including: reactive, proactive and strategic management. These strategies are discussed in detail in the following sub-sections. Most common resolution strategies are reactive in nature, as these provide "quick-fix" solutions once the obsolescence has already occurred. Many [30-35] recommend applying proactive obsolescence management strategies in order to minimize the risk of obsolescence and associated costs. However it is important to do the risk assessment (finding the probability of obsolescence) of all components in the BOM, before choosing a reactive or proactive strategy (Figure 2-4) [13]. If obsolescence of a component has low impact on costs then it may be advisable to use a reactive strategy as these strategies are easier to implement. If the probability of obsolescence is low and the impact is high costs, then it is advisable to use proactive mitigation measures. If both the probability of obsolescence and impact costs are high, then these components are regarded as 'critical' and hence, it is necessary to adopt a proactive mitigation strategy [13].

2.4.1 Reactive obsolescence management

Reactive strategies involve finding a solution once obsolescence has already occurred. There are various reactive resolution strategies that are used for obsolescence resolution. The following subsections give a brief explanation of these strategies [27].

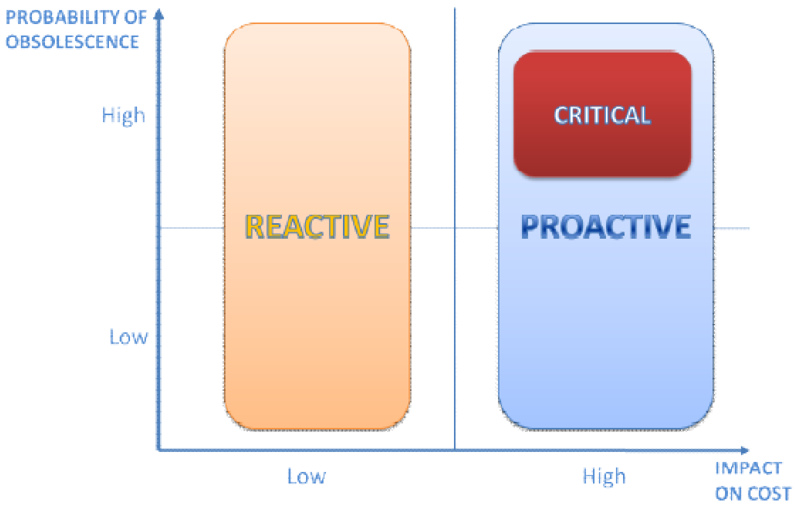

Figure 2-4 : Evolution of the level of obsolescence based on the management approach

2.4.1.1 Existing Stock

The use of existing stock describes the use of original parts from stock by the equipment manufacturer, as these parts were purchased from the original manufacturer. This is an inexpensive resolution strategy, as the cost incurred would be for inventory holding and functional testing.

2.4.1.2 Reclamation

Reclamation is the process of salvaging used or old parts that have a remaining useful life. This strategy is useful when the demand (of obsolete part) is small. However, this involves significant effort in handling (disassembly) and assessing the quality of parts to determine the potential for reuse.

2.4.1.3 Alternate parts

An alternate part provides a replacement part that may have equivalent or better performance than the part it replaces [25]. Alternate parts can be provided by the original supplier or by another manufacturer. If the parts have equivalent functionality then these parts can be used interchangeably.

2.4.1.4 Part Substitution

This refers to the process of selecting a replacement part that may or may not be match for one or more reasons, such as quality, tolerance, operating temperature range etc., and the performance of the substitute part may be less capable than the part it replaces.

2.4.1.5 Aftermarket

Aftermarket manufacturers provide support for the demand of parts after they are discontinued by the original equipment manufacturer. There are three types of aftermarket sources: authorized aftermarket sources that provide finished parts or assemblies, authorized aftermarket sources that remanufacture parts, and unauthorized aftermarket sources. (Bartels *et al.* 2012) [13].

2.4.1.6 Emulation

This is primarily applicable to electronic parts. Emulation is a process in which the unavailable electronic components are created from their slash sheets, datasheets, test vectors and other information. Emulated parts are sometimes categorized as substitute or alternate parts (Bartels *et al.* 2012) [13].

2.4.1.7 Redesign

This involves redesigning the obsolete parts via engineering changes in the product at different levels. This may involve a lot of testing and revalidation, especially if the part is used in avionic or military applications. Redesign is usually considered to be the last option, as it is an expensive strategy to implement as compared to other strategies.

2.4.1.8 Life Time Buy (LTB)

In the Life Time Buy strategy, the equipment manufacturer buys enough parts from the original part manufacturer in order to meet the system's lifetime needs (Bartels *et al.* 2012) [13]. This is one of the simplest solutions, as it does not require any requalification, testing or redesign. Usually the last date of ordering is notified by the original part manufacturer via Product Change Notification (PCN).

2.4.2 Proactive obsolescence management

Proactive obsolescence management deals with the problem of obsolescence before it actually happens. A key necessity for proactive management is forecasting of obsolescence dates of various components in a BOM. There are various forecasting approaches:

- Ordinal scale based methods: using a combination of technological attributes the life cycle stage of the product is determined [31].
- Based on product sales curve method: the life cycle curve of a product is obtained by fitting the sales data [5, 37, 38].
- Leading indicator methods: a leading indicator of a product can be further identified in each life cycle pattern of product that provides advanced indication of changes in demand trends [39].
- Using data mining techniques: "the method is a combination of life cycle curve forecasting and the determination of electronic part vendor-specific windows of obsolescence using data mining of historical last-order or last-ship dates" [38].

Lifecycle curve forms the basis of most forecasting models. Most electronic parts pass through various lifecycle stages corresponding to the changes in the sales of parts. Figure 2-5 represents the lifecycle curve of an electronic part, which has six common lifecycle stages, including: introduction, growth, maturity (saturation), decline, and phase-out, and also includes a seventh stage: obsolescence [5, 36].

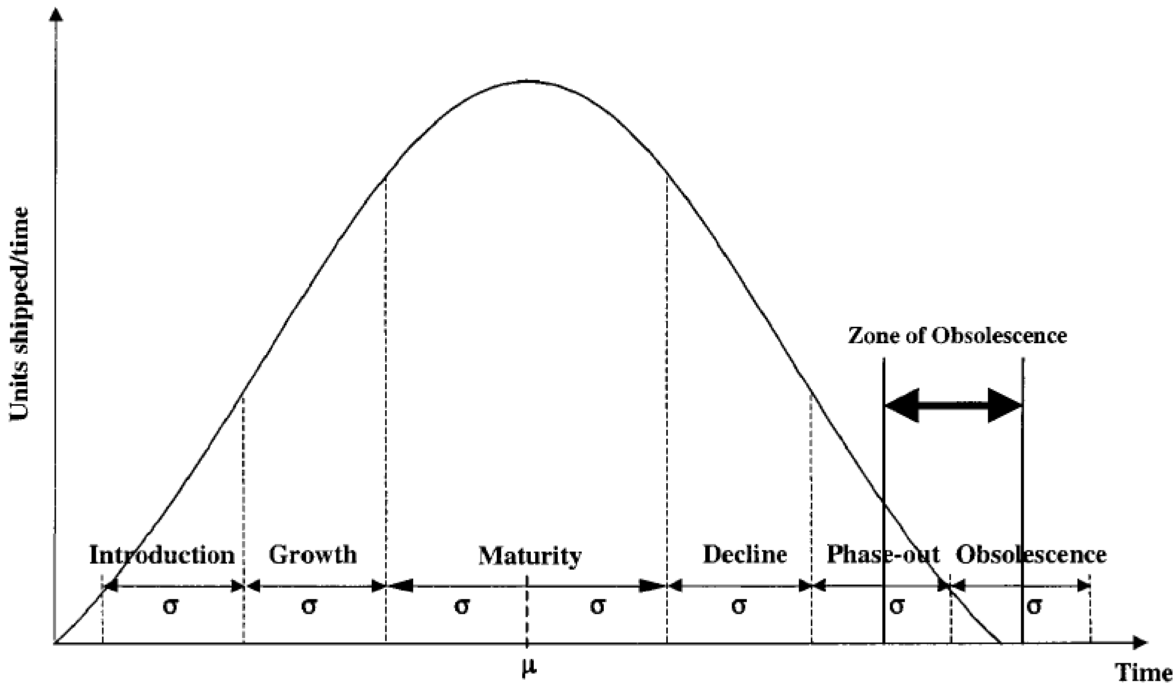

Figure 2-5 : Standardized product lifecycle curve

2.4.3 Strategic obsolescence management

Strategic DMSMS (Diminishing Manufacturing Sources and Material Shortages) management is a blend of reactive and proactive strategies. There are two types of strategic planning approaches that exist: Material Risk Indices (MRI) and Design Refresh Planning.

2.4.3.1 Material Risk Indices (MRI)

This approach analyses the BOM of a product and scores a supplier-specific part within the context of the enterprise using the part. MRI are used to combine the risk prediction from obsolescence forecasting with organization-specific usage and supply chain knowledge in order to estimate the magnitude of sustainment dollars put at risk within a customer's organization by the part's obsolescence [12].

2.4.3.2 Design Refresh Planning

For a long life system several design refreshes take place, which divides the lifecycle of the system into several time periods. If a component becomes obsolete between two planned design refreshes, a short-term mitigation approach (e.g., LTB, stock, aftermarket source, etc.) is applied on a component-specific basis until the next design refresh. When a planned design refresh is encountered, long-term mitigation solutions (e.g., substitute part, emulation, upgrade of similar part, etc.) are applied until the end of the system life or possibly until some future planned design refresh. Because these long-time mitigation solutions may result in design change, requalification may be required Figure 2-6 [12].

The design refresh planning model is proposed to determine the optimal redesign dates, which components should be considered for redesign, optimal LTB dates, and quantity. The goal of this model is to determine:

1. LTB quantity.
2. When to redesign.
3. Which components should be replaced at a specific redesign.

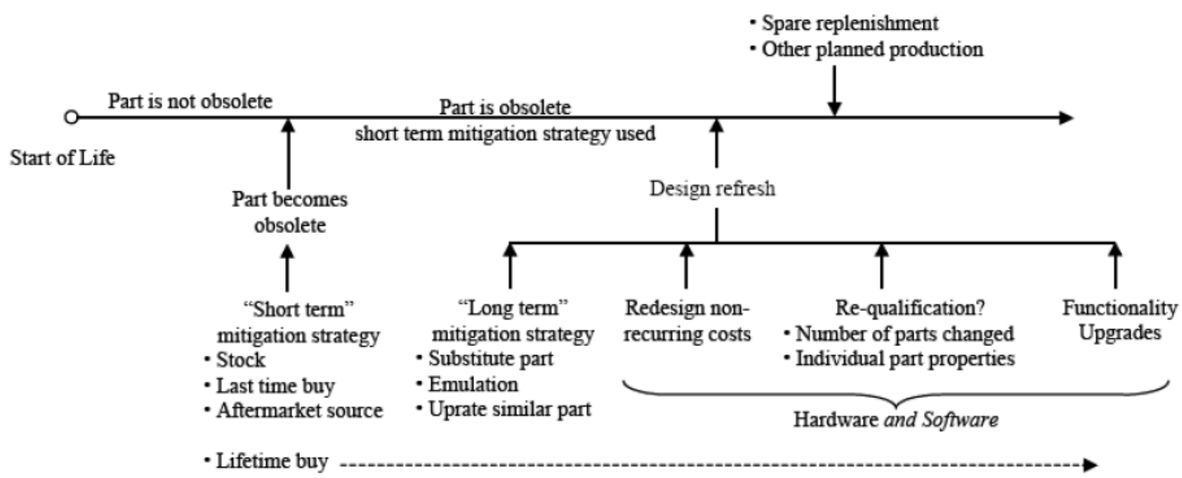

Figure 2-6 : Design refresh planning analysis timeline

2.5 Current Models in Decision Making

This section provides a summary of the present decision models that are used to manage obsolescence.

Porter [40] provided an approach for buy versus redesign based on economic analysis. It formulates the net present value of LTB and design refresh as a function of a date in future. The model performs its trade-off between last time buy costs and design refresh costs on a part-by-part basis. It provides Break-Even Year (Figure 2-7) chart that can be used as guidance for the engineering team to develop a solution for obsolescence management.

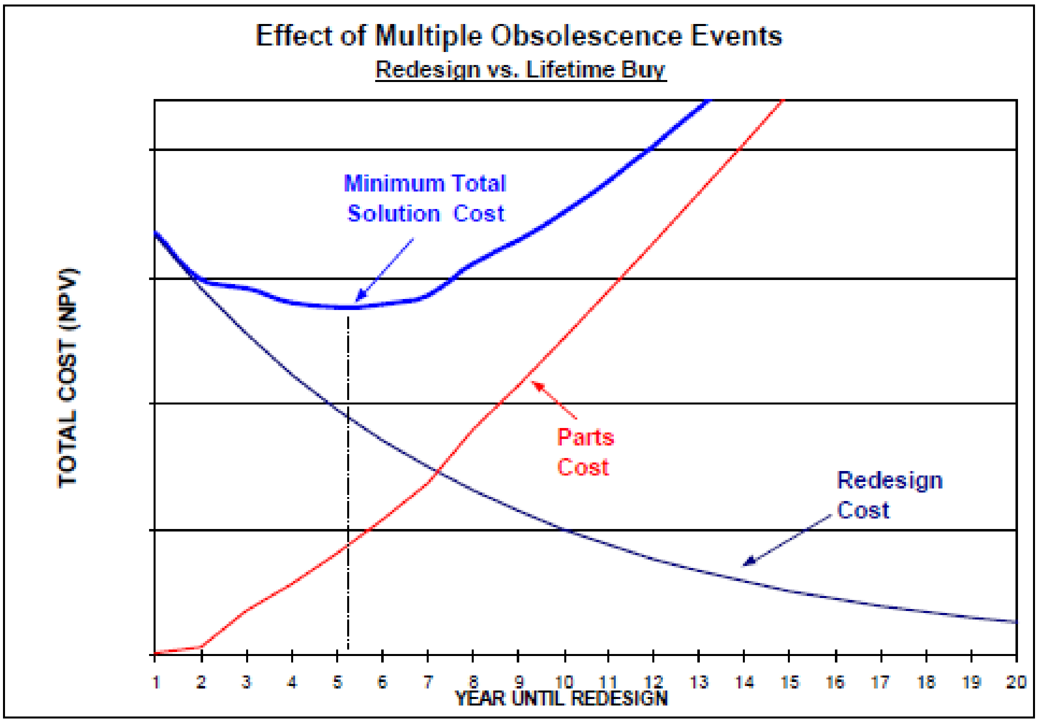

Figure 2-7 : Break-even year chart

Feng *et al.* [8] provides the list of factors that need to be considered while calculating the lifetime buy cost, which mainly includes procurement cost, inventory cost, disposition cost and penalty cost (Figure 2-8).

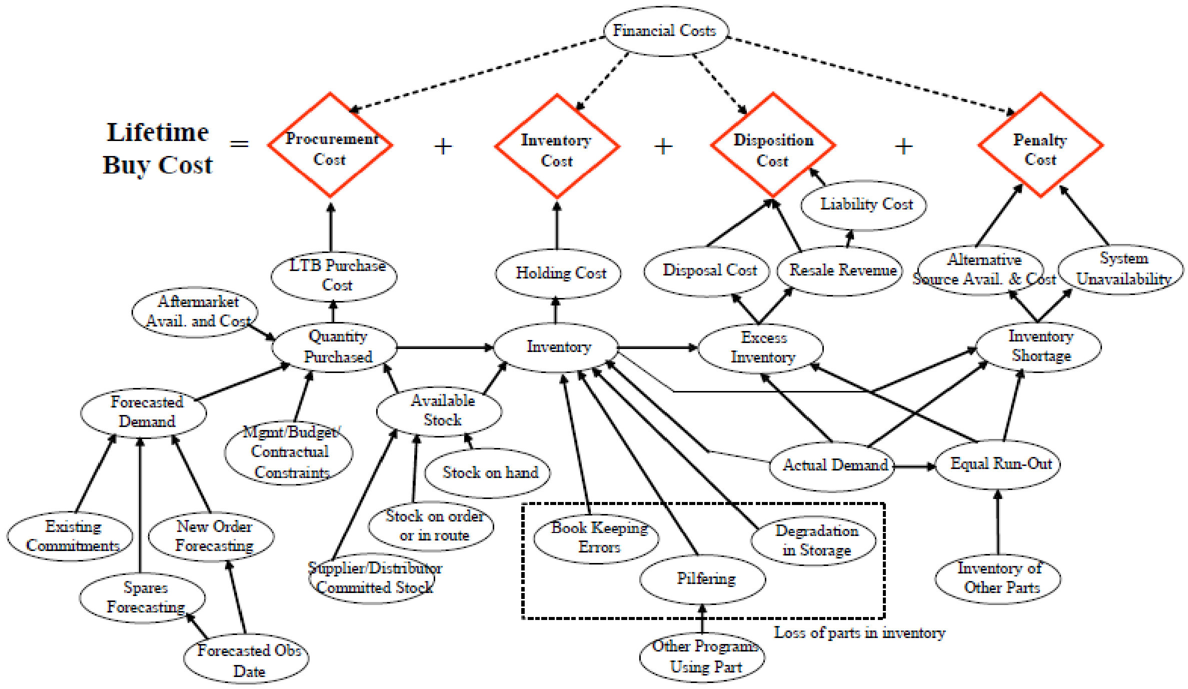

Figure 2-8 : Lifetime buy cost

Porter's [40] model fundamentally only considers a single design refresh at a time. A more complete optimization approach to refresh planning, called MOCA [12], has been developed that optimizes over multiple refreshes and multiple obsolescence mitigation approaches. The MOCA methodology uses a detailed cost analysis model and determines the optimum design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities, their content and respective calendar dates that minimize the through-life sustainment cost of the product (Figure 2-6).

Zheng *et al.* [41] presented a mathematical model based on integer programming that determines a design refresh plan that minimizes total cost. The approach provides guidance on when to execute design refreshes and which obsolete/non-obsolete system components should be replaced at a specific design refresh. The model also considers the uncertainty related to obsolescence dates. With this approach, different scenarios of executing design refreshes and the probabilities of adopting these scenarios can be determined.

Dinesh *et al.* [42] used a restless bandit model that can be used to calculate the impact of various obsolescence mitigation strategies on the total cost of ownership of a system.

Teuntera and Fortuin [43] deal with finding (close to) optimal final-order quantities. The outcome is an explicit formula that gives close-to-optimal final-order quantity.

Hu and Bidanda [44] formulated a product life-cycle evolution system based on stochastic dynamic programming (SDP). A Markov decision process is used to model sequential decision making throughout product life-cycle management. The model is able to provide guidelines to the decision maker in a way that final optimal cost becomes an expected value.

Meng *et al.* [44] presents a mathematical model for obsolescence management, which combines graph theory and mixed integer linear programming to give an optimal schedule for redesign that minimizes the obsolescence management cost.

2.6 Summary and Research Rationale

As discussed in this chapter, obsolescence management is of high importance in sustainment dominated systems. While there are tools and approaches that help decision making for obsolescence management, most of these techniques use “minimize overall cost” as the primary or sole criteria. Key research gaps are summarized as follows:

- The need for decision support in obsolescence management that considers various factors, beyond cost-only approaches.
- The need for an obsolescence management strategy that involves the views of multiple stakeholders in decision making.

The next chapter presents the objectives of this research and describes the development of the research methodology.

CHAPTER 3 : RESEARCH METHODOLOGY

The selection of an ORS depends on a wide range of factors, the decision maker needs to analyze the trade-offs among these factors and choose the most suitable strategy to mitigate obsolescence. Figure 3-1 shows the key factors that need to be considered in the decision making process in obsolescence management.

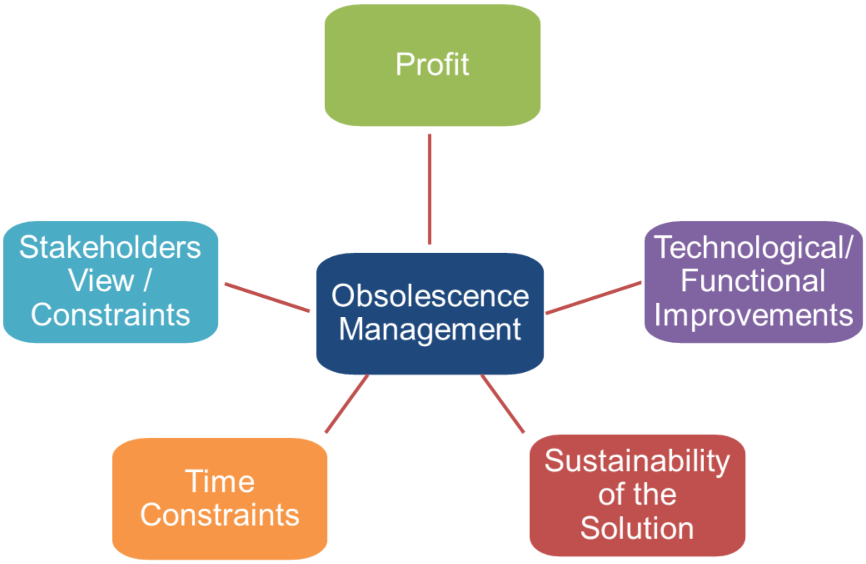

Figure 3-1 : Taxonomy of the factors affecting ORS

This chapter explains the relevance of these factors in obsolescence management and then provides a multi criteria decision model based on Multi Attribute Utility Theory (MAUT) to choose the most suitable ORS.

3.1 Factors Affecting Decision Making

3.1.1 Stakeholders Opinion

Figure 3-2 shows a typical Obsolescence Management Plan (OMP). The process begins when the decision maker receives a Product Change Notification (PCN) from a supplier.

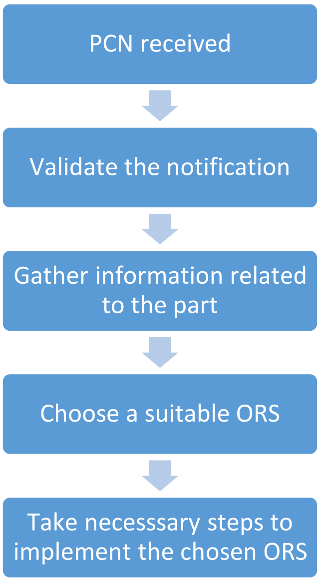

Figure 3-2 : Obsolescence Management Plan (OMP)

The first task of the decision maker is to validate the notification, i.e. analyze the impact of “the change/upgrade in a part” on the part itself and on the product. If it is just a minor change (such as change in part id, code, packaging, company name and logo etc.), which does not affect the functionality of the part/product, then no further action is needed. If the change in part causes a change in the functionality of the part or product, or if the PCN is an End of Life (EOL) notification (supplier is no longer going to manufacture the part), then the decision maker has to choose a suitable ORS to mitigate obsolescence. The decision maker collects information, such as expected demand of the part, cost of the part, availability of resources to perform a redesign and expected lifetime of the part and the product etc., from various departments. In the next step the decision maker analyzes the gathered information and selects the most suitable ORS. The final step in the OMP is to implement the chosen strategy, which may involve one or a few of the following:

- updating the product/part database
- finalizing the order quantity for procurement

- preparing the new design
- selecting suppliers
- providing guidelines for maintenance and service of replacement part/assembly to customer and/or the maintenance team
- performing design revalidation
- performing quality analysis of the replacement part

There are multiple departments that contribute in implementing an ORS or might be affected by implementation of an ORS, which makes these departments the stakeholders in the decision making process, Figure 3-3 shows the key stakeholders.

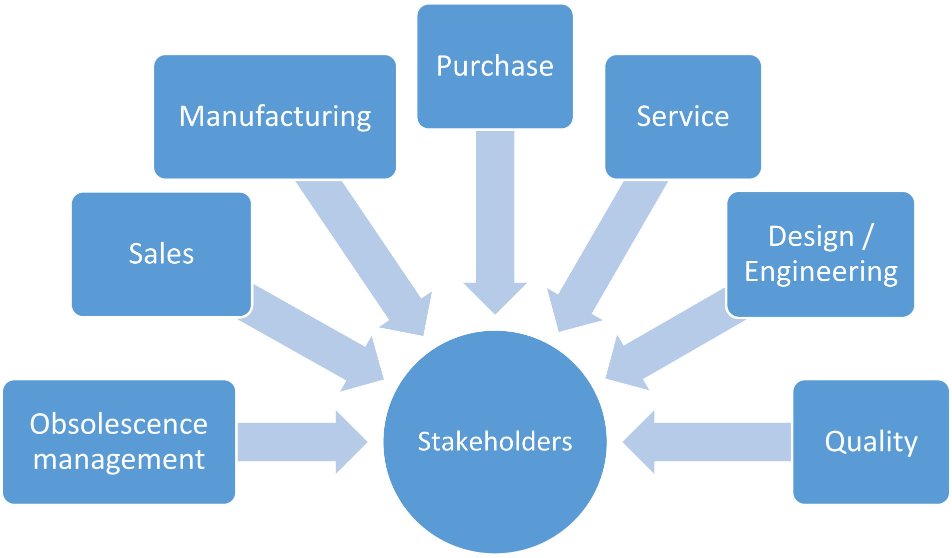

Figure 3-3 : Stakeholders

Sections 3.1.1.1 to 3.1.1.7 discuss the influence that the stakeholders have in OMP.

3.1.1.1 Obsolescence management

The obsolescence management team is the decision maker in the OMP. Its role is to develop and implement processes that predict obsolescence of various parts or products and develop strategies to mitigate obsolescence. The database of parts and products is the primary resource of this team and obsolescence management centers around it. The primary responsibilities of this team are to:

1. Manage the database and keep track of obsolescence status of parts and products.
2. Analyze the information gathered from product change notifications sent by suppliers and update the database accordingly.
3. Communicate the changes in the part to concerned departments or personnel.
4. Prepare the obsolescence mitigation plan for the concerned part.
5. Monitor the implementation process of the ORS

3.1.1.2 Sales and Marketing

Sales and marketing plays a vital role in the profitability of the business. From an obsolescence management perspective the sales team has following responsibilities:

1. Predict the demand of the product or the part until the next redesign or end of life of the product.
2. Predict the expected life-time of the product based on the market trends.
3. Provide the information related to customer reviews/feedback.

The input given by the sales team is used to decide the order quantity of the obsolete part and to check if there is any need (due to market trends) for upgrades or changes in the product for performance or technological improvement.

3.1.1.3 Manufacturing

Manufacturing department is responsible to produce the goods that the company sells. It is important for the decision maker to understand the capabilities of the existing manufacturing setup before choosing an ORS, as the changes in the setup can be very expensive. In the context of obsolescence management the input from manufacturing team is important in order to

1. Estimate the time required for the manufacturing of new parts or the prototype.
2. Check if the manufacturing of new part needs any changes in the manufacturing setup and estimate the cost associated with the required changes.
3. Explore the possibility of improvement in the performance. In some industrial sectors, such as military and defense redesign needs revalidations, which is costly and time consuming. This means that the upgrades in the products are not frequent, but when a redesign is scheduled manufacturing team can provide recommendations related to manufacturability of the product, which can help improve the performance of the product.

3.1.1.4 Purchasing

The primary responsibility of this team is to purchase parts or material from various suppliers in right quantity and as per the schedule. The purchasing team identifies various sources for supplies and then conducts the preliminary negotiations with suppliers. From an obsolescence management perspective the purchasing team has following responsibilities:

1. Analyze the supplier's reliability based on past performance.
2. Verify if the supplier meets the required criteria such as ISO certifications or defense clearances.

3.1.1.5 Engineering / Design / Research and Development

The primary responsibilities of the design team are to create designs for new product, provide design solutions for ongoing projects, prepare the bill of material for manufacturing and troubleshoot the issues related to manufacturing or installation of the product.

From an obsolescence management perspective, the design team plays an important role in the implementation process. For example in case of “Redesign” the design team provides the design of the new assembly or product for manufacturing, for “Alternate” or “Substitution” the design team might have to perform the testing and validation of the new part using simulation or Finite Element Analysis (FEA). The key constraints for the design team regarding obsolescence management are:

1. Availability of resources (engineers, software required for simulation/FEA) to perform redesign or testing.
2. Time available for redesign or testing.

The inputs from the design team helps the decision maker to calculate the required time and cost for implementing an ORS.

3.1.1.6 Quality

This department is responsible for preventing mistakes or defects in manufactured or purchased products and avoiding problems when delivering solutions or services to customers. The responsibilities of this group in obsolescence management are

1. Check the quality of reclaimed parts.
2. Check the quality of parts procured from aftermarket sources.
3. Check the quality of parts from suppliers and give the feedback to the decision maker.

3.1.1.7 Service

The role of the service team is to provide maintenance and support to the products installed at the customer’s site. This team can give feedback to the design team, such as service life of parts, performance of the parts, which can be used to improve the designs during redesign. A redesign or a replacement might require service personnel to undergo training in order to learn new troubleshooting procedures for redesigned or replaced parts, which may lead to additional time and cost for the implementation of an ORS.

3.1.2 Profit

Profit is the bottomline of a business and the majority of decisions in a company are made to maximize profit. Profit can be calculated using a simple equation

$$\text{Profit} = \text{Quantity} * (\text{Selling Price} - \text{Costs})$$

In the consumer electronics industry, demand is highly dependent on market forces and is highly volatile in nature. The price of the product and quality play a key role in market demand of the product. A high quality product with high price and high profit per unit may end up giving less business due to lower demand, whereas a moderate quality product with moderate profit per unit may give higher revenues due to higher demand. In case of long life systems such as space, defense etc. the demand is relatively steady and the priority is mainly on keeping the systems functional with objectives to provide a compatible part and minimize the cost. Therefore the decision maker must consider the effect of an ORS on the quantity (demand), selling price and the cost price of the part/product while making a decision.

Figure 3-4 shows a holistic view of the factors that needs to be considered while calculating the cost of implementing an ORS [10]. The decision maker must consider the factors that are relevant to an ORS.

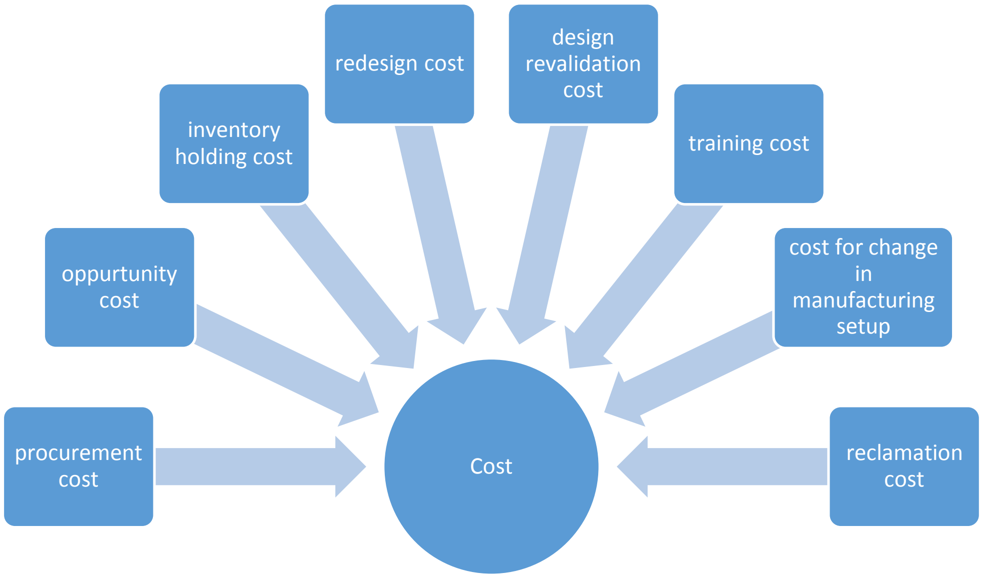

Figure 3-4 : Factors affecting cost

3.1.3 Functionality

Figure 3-5 shows two key aspects related to the functional performance in an OMP:

1. The functionality/performance of the part/product should be within the acceptable range after implementing the ORS.
2. Identifying any need for performance improvement of the product or part.

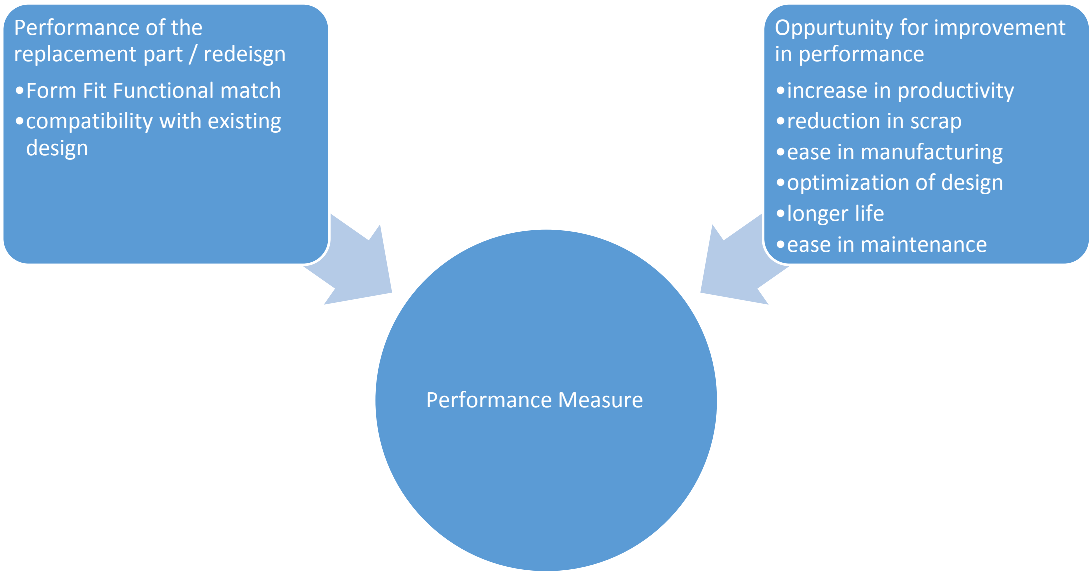

Figure 3-5 : Performance / Functional Measure

The form fit function (FFF) of the replacement part should be compatible with the original part/product and the performance of the system must not denigrate or in certain applications performance must not change. In strategies such as “substitute” or “reclaimed part”, the functionality of the replacement part may not be at par to that of the original part, the decision maker must ensure that the replacement part meets all the system requirements.

Moreover, obsolescence issue can also be seen as an opportunity to improve the functionality or the performance of the product. By choosing a better alternative part or a minor redesign the performance of the product/part can be improved. The feedback from various stakeholders can prompt a change in the design for improvement in the system, some of the possible improvements are as follows:

1. Increase in productivity: faster assembly of parts could lead to higher output.
2. Reduction in scrap: with the new part or design, the scrap could be reduced leading to cost saving benefits.
3. Improvement in performance: there could be an improvement in the overall performance of the system, for example in case of a computer reduction of processing time, for a cell phone improvement in battery life, and for a mechanical part extension in fatigue life. Following shows some possible performance improvement measures:
   - Reduction in processing time
   - Longer life span of the part/product
   - Higher fatigue life
   - Improvement in material properties, such as thermal properties,
   - Higher service life

3.1.4 Reliability of vendors

As discussed in Chapter 2, one of the primary reasons for obsolescence is discontinuance of the part by a supplier. Therefore it is necessary to choose reliable vendors in order to avoid reoccurrence of obsolescence of the part or the product. Figure 3-6 shows the primary factors that need to be considered while choosing a vendor in case of obsolescence management. The decision maker has to rely on the experience and the knowledge of the purchase department and records of the past transaction with vendors in order to choose reliable vendors for a sustainable obsolescence management plan.

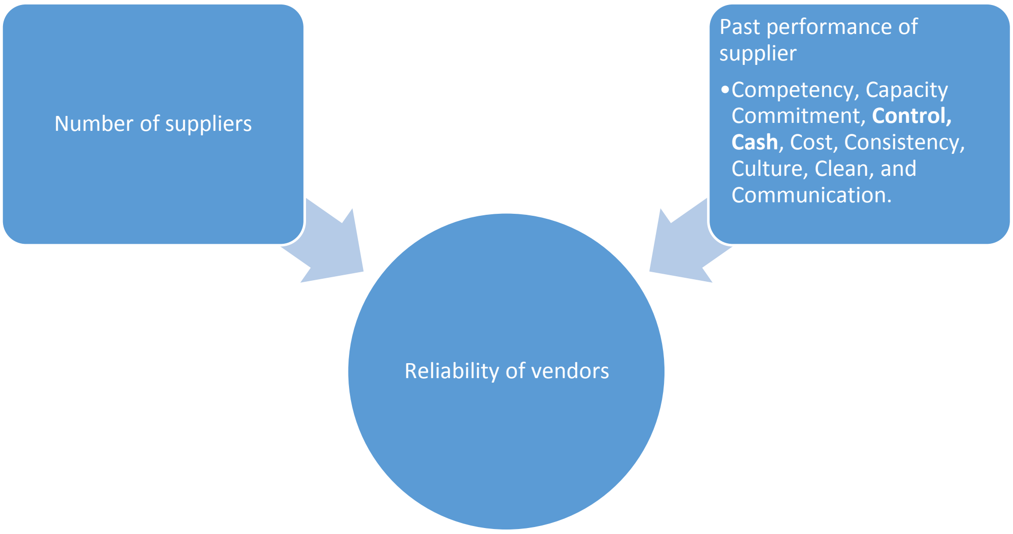

Figure 3-6 : Reliability of vendors

3.1.4.1 <u>Number of vendors</u>

If there are multiple vendors available for the same component then the risk of obsolescence decreases, as there are backup suppliers in case the preferred/primary supplier goes out of business or decides to end the production of the part.

3.1.4.2 <u>Past performance of vendor</u>

A lot of research has been done in the field of supplier performance evaluation and companies adopt various strategies to evaluate the performance of suppliers. The 10Cs of effective supplier selection as proposed by Ray Carter [51] provides the parameters that need to be considered for supplier selection / evaluation. These include: Competency, Capacity Commitment, Control, Cash, Cost, Consistency, Culture, Clean, and Communication. Traditional evaluation of suppliers does not necessarily look at factors associated with product support and supportability decisions of components in the long term. From obsolescence perspective Control and Cash play an important role in the selection of vendors. Control means how much control the vendor has on its own supply chain, and Cash means the financial health of the supplier.

If the vendor (primary) has the capabilities of manufacturing the part without much of dependency on other suppliers (secondary) then the decision maker has to only consider the financial stability of only the primary vendor for future business. However if the vendor is dependent on multiple suppliers then the risk of obsolescence increases due to increase in the number of suppliers in the supply chain network.

One important factor that needs to be considered for a sustainable supply chain is "obsolescence decision for financial advantage". As the customers have limited choices for obsolescence mitigation, a vendor may deliberately force obsolescence of parts to initiate a LTB and pull future revenues in the current fiscal cycle in order to boost revenues [46]. So from an obsolescence management perspective, the financial stability of vendors becomes an important factor in selection of vendors.

For this research a scorecard methodology is used to assign rating (on a scale of 10), to different suppliers. (See appendix A)

3.1.5 Time constraint

An EOL notification gives the decision maker a final order date and the decision maker has to choose a suitable ORS before the final order date. Figure 3-7 shows a typical timeline of a product from EOL notification of a part (point A) to EOL of the product or until the next planned redesign of the product (point E). If the decision maker selects LTB as the ORS then the final order has to be placed before the final order date (point E), however if the chosen ORS is other than LTB then the decision maker has to consider the time required for the implementation of the chosen ORS to maintain the support to the existing product. If the time required for implementation goes beyond the final order date as shown in the Figure 3-7 then the decision maker must ensure the availability of the part in the overlap period (time period between points C and D). This can be achieved by placing an order (the quantity is based on demand between C-D) before the final ordering date. This is a critical factor in high volume industries such as consumer electronics, where it is vital to meet the consumer demand and a short supply of goods may damage the brand reputation and the market share.

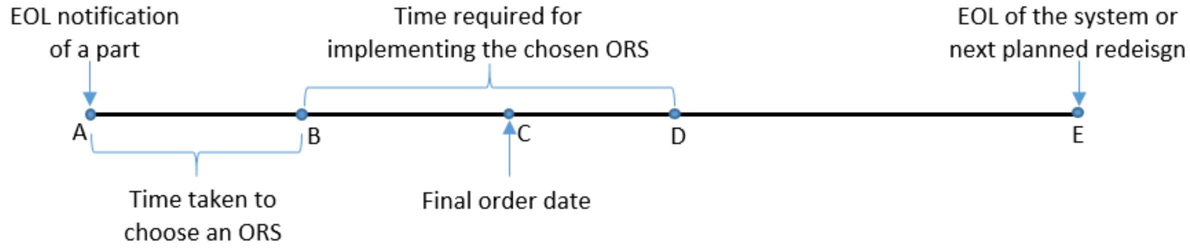

Figure 3-7 : Timeline from EOL of a part to EOL of the system

Figure 3-8 shows some of the important factors that must be considered to estimate the time required for the implementation of an ORS.

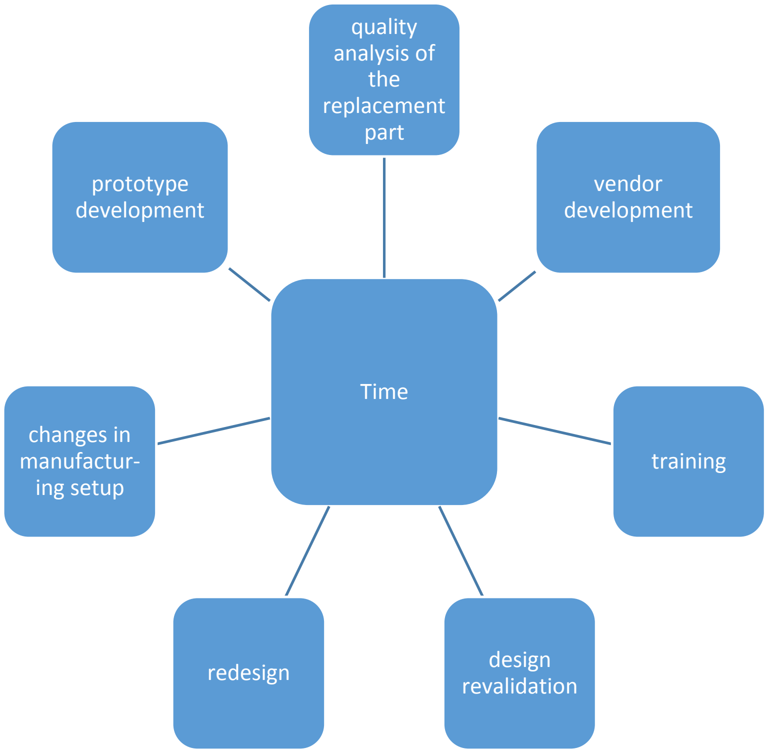

Figure 3-8 : Factors affecting the implementation time of an ORS

3.2 Decision Model

The selection of an ORS is based on qualitative (opinion of the stakeholders) and quantitative factors (cost, time and performance) and involves performing the trade-offs among these factors. There are different obsolescence resolution strategies available for a decision maker to choose from and selection of an ORS may vary based on the application area and the market strategy of the company. The decision maker needs to compare the strengths and weaknesses of these strategies with regard to multiple objectives and inputs from various stakeholders involved in the decision making. This research uses Multi-Attribute Utility Theory (MAUT) to choose a suitable ORS. MAUT is a structured, logical and systematic methodology that can handle trade-offs among multiple objectives, it integrates qualitative/subjective factors, such as decision maker's risk attitudes or experience, into objective factors such as profit-loss of a project.

3.2.1 Multi Attribute Utility Theory (MAUT)

The basic principle of MAUT is to first clearly define the goal, then identify the single attributes that can reflect the decision objective; next calculate the utility value of each attribute and evaluate the weight of every attribute; then select an appropriate model to aggregate the single utility values into multi attribute utility value; and finally, select the optimal alternative based on the total utility value [47].

3.2.1.1 Objective hierarchy

The first step in using MAUT methodology is to identify the objectives and categorize the objectives into fundamental and means objectives. Fundamental objectives are those that one wants to accomplish ultimately and means objectives are those that help achieve other objectives. Next, an objective hierarchy is created that shows various fundamental and means objectives that help achieve the ultimate goal.

3.2.1.2 Utility and utility function

In economics, utility refers to the total satisfaction received from consuming a good or service and is often used to measure people's subjective attitude or preference to certain things. The utility value lies between 0 and 1, 0 being least desired and 1 being most desired. In decision analysis, the decision maker's experience of profit and loss is referred to as "utility function", and it is written as "u(x)". It is consecutively derivable in R, and $u'(x)>0$. Different decision maker has different risk preference, so the degrees of acceptance to the same profit and loss are also different, accordingly, their utility function curves are different [48]. Usually, there are three types of decision makers (Figure 3-9):

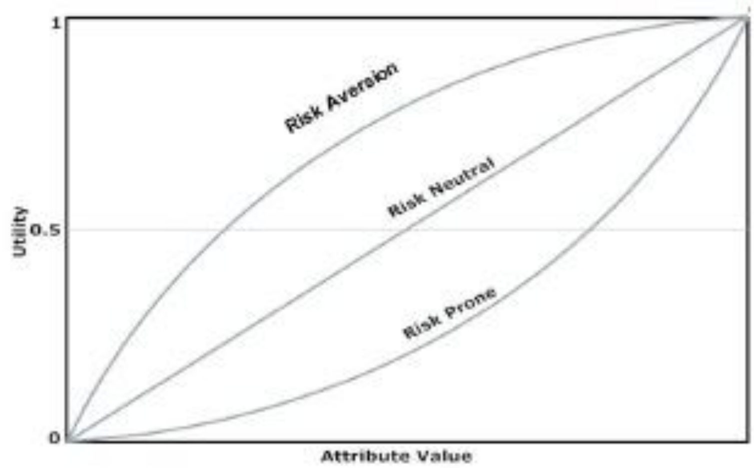

Figure 3-9 : Three types of single-attribute utility function

1. Conservative decision makers (risk-averse behavior): u(x) is convex function, u"(x)<0.
2. Adventure decision makers (risk-seeking behavior): u(x) is concave function, u"(x)>0.
3. Neutral decision makers (risk-neutral behavior): u(x) is linear function, u"(x)=0.

The first step in the process is to determine the utility for each attribute and then multiple attributes are aggregated using either the additive utility function or the multiplicative utility function.

Utility function has many forms, such as exponential curve, logarithmic curve, linear curve, hyperbolic curve etc., and among these forms, the exponential curve is the most widely used. Single attribute utility function, based on exponential curve, is given by Equation 1

$$u(x) = a - be^{-cx} \quad (1)$$

Where, a, b are constants, and c is the risk aversion coefficient. A value of c>0 means risk-averse behavior, c<0 means risk-seeking behavior, and c approaching zero means risk-neutral behavior. The reciprocal of the risk aversion coefficient (1/c) is the risk tolerance of decision makers [48]. By defining three certainty equivalent points of utility, and then solving the simultaneous equations, we can get the expression of the utility function. Typically the three points are the maximum utility point (u=1), the minimum utility point (u=0) and the median utility point (u=0.5) [49].

Another way to assign utility values is by assigning utility values to the individual attributes based on the experience of the stakeholders or the decision maker. This is used when there are just a few attribute values in the least preferred and the most preferred range.

There are two common methods to aggregate the single utility functions: additive model and multiplicative model.

If attributes are independent with each other, the additive model is appropriate and it is expressed as:

$$U(x_1,\ldots,x_m)=\sum_{i=1}^{m} w_i u_i(x_i) \qquad (2)$$

Where, x_i is the assessment unit for attribute i, $u_i(x_i)$ is the decision maker's preference or utility value for x_i; and $w_i \geq 0$ is the weight of attribute i, and $\Sigma w_i=1$.

If the attributes are correlated with each other, the multiplicative model is appropriate and it can be expressed as:

$$U(x_1,\ldots,x_m)=\frac{\{\prod_{i=1}^{n}[1+Kk_i u_i(x_i)]\}-1}{K} \qquad (3)$$

Where, k_i is a scaling factor satisfying $0\leq k_i\leq 1$, and K is an additional scaling constant satisfying:

$$1+K=\prod_{i=1}^{n}(1+Kk_i) \qquad (4)$$

For this research, additive utility theory (AUT) is chosen, as it is a practical methodology due to its easier computational analysis and it is easier to understand and explain to decision makers.

3.2.1.3 Evaluating weights

In order to aggregate the single utilities using the additive utility function, the weights in equation 2 need to be determined. In this research the swing weight methodology is used to determine the weights, as it gives the stakeholders an opportunity to express their preferences related to various measures. Assigning weights using swing weight methodology involves following steps [50]:

1. Vote: each stakeholder assigns 100 points over the value measures based on the importance of the measure and range of variation in the measure scale.
2. Identify and discuss significant differences. Discuss the rationale behind the "outliers".
3. Revote until the group agrees on the ranking of the value measures.
4. Vote again requiring each person's weights to follow the group's ordinal ranking of the value measures.
5. Average the weights (cardinal ranking of weights) and normalize so they sum to one.
6. Identify and discuss significant differences. Discuss the rationale behind the "outliers".
7. Repeat steps 4-6 until the group agrees on the normalized cardinal weights. If the group cannot resolve all disagreements about the weights, the disagreements must be noted. When alternatives are evaluated, sensitivity analysis is done to check the significance of the weights.

3.2.1.4 Rank order

Next step is to aggregate the utilities for all the alternatives using equation (2) and rank order the alternatives based on the overall utility function value. The alternative with the best utility value is chosen as the strategy for the given case.

3.3 Conclusion

This chapter highlights the importance of some of the crucial factors that affect the decision making in obsolescence management. It explains why it is important to consider the experience of different departments (stakeholders) while choosing an ORS. Finally, the chapter concludes with an explanation of MAUT and outlines the various steps involved in implementing MAUT to make a decision.

CHAPTER 4 : MAUT FOR OBSOLESCENCE MANAGEMENT

4.1 Objective hierarchy

A model based on MAUT has a clearly defined goal/objective, in this research the goal of using MAUT is to select the most suitable ORS to manage obsolescence. The factors that affect the decision making were discussed in Chapter 3 and based on these factors an objective hierarchy is created. Table 1 shows the fundamental objectives and the means objectives to select the most suitable ORS. It is a generalized framework that reflects only some of the factors, in a real life problem the decision maker must do a detailed analysis based on the application and create a more specific objective hierarchy.

Table 1 : Objective hierarchy for obsolescence management

Fundamental Objectives	Means Objectives
Maximize profit	Demand
	Selling price
	Cost
Maximize functional upgrade	Productivity
	Speed
	Waste
	Manufacturing time
	Life span
	Process optimization
Maximize reliability of ORS	Number of suppliers
	Past performance score
	Required supplier certifications
Minimize time required for implementation	Time for redesign
	Time for quality verification
	Time for documentation
	Time for training
	Time for change in manufacturing setup
	Time for reclamation

4.2 Example Case

The following section uses a hypothetical example that demonstrates how to use MAUT to select a suitable ORS.

ABC is a hypothetical computer manufacturing company that procures sub-assemblies from various suppliers and assembles computer at its facility. One of the critical parts of the computer is RAM and the supplier that provides RAM for one of their computer models has issued a PCN for end of life notification. The obsolescence management team has to choose a suitable ORS, such that the company can manufacture and supply the same computer until the end of life of the product without any major redesign in the computer design. The decision maker has three obsolescence resolution strategies (parts) to choose from: substitute, life time buy and alternate. Table 2 shows the technical specifications of the parts in the three strategies.

Table 2 : Technical specifications of the parts

	Substitute	Current design (LTB)	Alternate
RAM specification	2GB DDR3 PC3-12800 Unbuffered NON-ECC 1.35V	4GB DDR3 PC3-12800 Unbuffered NON-ECC 1.35V	4GB DDR3 PC3-14900 Unbuffered NON-ECC 1.35V
compatible with existing design	Yes	Yes	Yes
Memory size	2 GB	4 GB	4 GB
Data rate (MT/s)	1600	1600	1866

Two key parameters to compare the performance of different RAMs are data rate and memory size. For a better performance of the computer higher data rate and higher memory size are desired.

4.2.1 Objective hierarchy

Based on the given information an objective hierarchy is created, as shown in Figure 4-1. The objective is to select the most suitable ORS, the fundamental objectives (goals) are: maximize profit, maximize functional upgrade, maximize vendor reliability and means objectives are: minimize time required for implementation of the strategy, minimize cost, maximize selling price, maximize demand, maximize data rate, maximize memory size, maximize past performance score of chosen supplier, maximize number of suppliers and minimize time for training, documentation, ordering and design revalidation.

The research presents two examples (hypothetical) that shows how the decision might vary based on the area of application and the priorities of the stakeholders for a particular case. All the analysis and calculations are done using a tool called "Logical Decisions" (see appendix B)

Figure 4-1 : Objective hierarchy for the case study

4.2.2 Case 1

In first case the computers are sold to individual users (personal/office computers). This implies that for a replacement part a design revalidation is not required, provided that the replacement part satisfies the system requirements. The market study done by marketing team suggests that the demand of the product will increase if the system is upgraded and there is a possibility of decrease in demand if the performance of the system degrades due to the replacement part. Table 3 shows the expected values of cost, demand and selling price of the product, which is based on the market research.

Table 3 : Profit-cost matrix for the three strategies

	Substitute	LTB	Alternative
forecasted demand until EOL of the product	6800	7500	8200
selling price, $	480.00	480.00	490.00
cost of this part, $	13.99	22.99	24.99
implementation cost (per part) , $	3.50	1.20	3.50
cost of other parts, $	400.00	400.00	400.00
total cost, $	415.49	424.19	428.49
Profit, $	425068.00	418575.00	504382.00

For “substitute” the performance of the product degrades due to the reduction in memory size and this will lead to reduction in demand. Whereas, for the “alterative” part the performance of the product will improve due to higher data rate, hence the demand is expected to increase.

The implementation cost is an approximate value, for a real case it will include the inventory holding cost, opportunity cost, transportation cost, design revalidation cost, cost for buffer stock and training cost and many other factors. For the given case the implementation cost for substitute and alternative is considered relatively higher compared to the LTB due to the additional costs associated with quality analysis of the replacement part.

4.2.2.1 Utility Values

Table 4 shows the attribute values for different measures for the three available parts. Based on the inputs from the stakeholders the decision maker decides the most preferred and the least preferred attribute values for each measure, and based on the risk preferences assigns the attribute value for a measure at utility value of 0.5 (see appendix C for risk preferences)

Table 4 : Attribute values for different measures

	Substitute	LTB	Alternative	Most preferred	Least preferred	attribute value at utility 0.5
Profit ($)	425,068	418,575	504,382	500,000	320,000	360,000
Memory size (GB)	2	4	4	8	1	-
Data rate (MT/s)	1600	1600	1866	1866	1333	-
Rating of the chosen supplier on a scale of 10	8	8.5	8	10	6.5	7.25
Number of suppliers	1	4	3	4	0	-
Time required for implementation (days)	35	25	35	21	70	60

For memory size, data rate and number of suppliers there are only a few attribute values in the range between least preferred and the most preferred and it is more efficient for a decision maker to assign utility values directly to every attribute value. These utility values can be assigned based on the recommendation from various stakeholders. Tables 5, 6 and 7 show the utility values for memory, data rate and the number of suppliers respectively. In case of LTB a final order is made, therefore the number of suppliers does not affect the reliability and a utility value of 1 is assigned to this measure.

Table 5 : Utility values for memory

Memory (GB)	1	2	4	8
Utility value	0	0.5	0.8	1

Table 6 : Utility values for data rate

Data rate MT/s	1033	1333	1600	1866
Utility value	0	0.5	0.8	1

Table 7 : Utility values for number of suppliers

Number of suppliers	0	1	2	3	4
Utility value	0	0.5	0.75	0.85	1

Using Equation 1 and Tables 4, 5, 6 and 7 the utility values for all the attributes of various measures are calculated and are as shown in Table 8.

Table 8 : Utility values of rest of the measures

	Substitute	LTB	Alternative
Profit	0.862	0.840	0.952
Memory size	0.500	0.750	0.750
Data rate	0.800	0.800	1.000
Rating of the chosen supplier	0.762	0.818	0.864
Number of suppliers	0.750	1.000	0.850
Time required for implementation	0.937	0.987	0.937

4.2.2.2 Weights

Based on the discussion between various stakeholders and the decision maker the rank order for the fundamental objectives is decided. Using swing weight methodology, as discussed in section 3.2.1.3, the final weights for fundamental objectives are assigned as shown in Table 9.

Table 9 : Weights for fundamental objectives (goals)

	Rank order	Weights on a scale of 100	Normalized weight
Profit	1	100	0.33
Functional upgrade	2	90	0.30
Reliability of vendors	3	60	0.20
Time required for implementation	4	50	0.17

Similarly the weights for the means objectives for vendor reliability and functional upgrade are calculated as shown in Table 10.

Table 10 : Weights for means objectives

		Rank order	Weights on a scale of 100	Normalized weight
Functional upgrade	Memory	1	100	0.53
	Data rate	2	90	0.47
Vendor reliability	Past performance score	1	100	0.54
	Number of suppliers	2	85	0.46

The company is in the business of consumer products, hence the profit margin and the brand reputation is of high priority, which is reflected in the rank order of weights. There are plenty of suppliers that can provide replacement parts, therefore the reliability of vendors does not have a high priority. Time required for implementation for this case is not of very high importance.

4.2.2.3 Result

Using equation (2) the weights and utility values of all the measures are aggregated and the final utility value of each strategy is calculated. The final rank order of strategies based on maximum utility value is created, as shown in Figure 4-2.

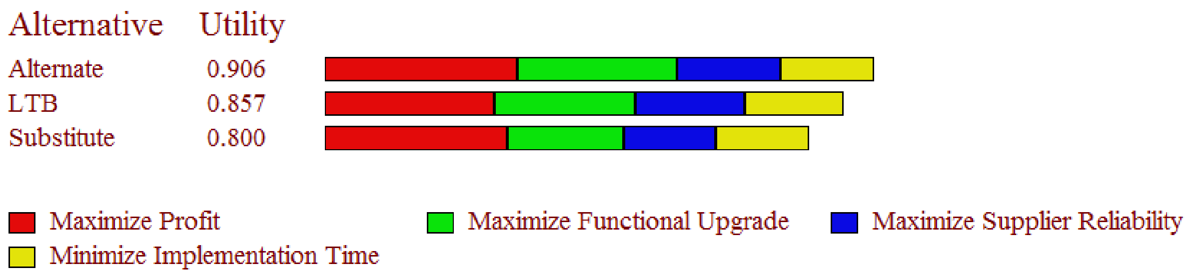

Figure 4-2 : Rank order of the three strategies

The strategy with highest utility value is chosen, so for this case the most suitable ORS is “Alternate”.

4.2.2.4 Robustness of the result

The result is based on subjective evaluation of weights by various stakeholders, so there is a possibility that the solution might be too sensitive to the weights assigned to various goals, therefore it is important to check the robustness of the solution. Using "sensitivity analysis" option available in Logical Decision software the sensitivity analysis of the result is done. The tool can be used to plot the impact of weights assigned to various goals on the rank order.

Figure 4-3 shows the impact of weights assigned to goal profit on rank order. The vertical line represents the current weight to "profit" goal (0.33). It can be seen that even with change in the weight "Alternate" remains the best solution, hence the result is insensitive to weight assigned to "profit".

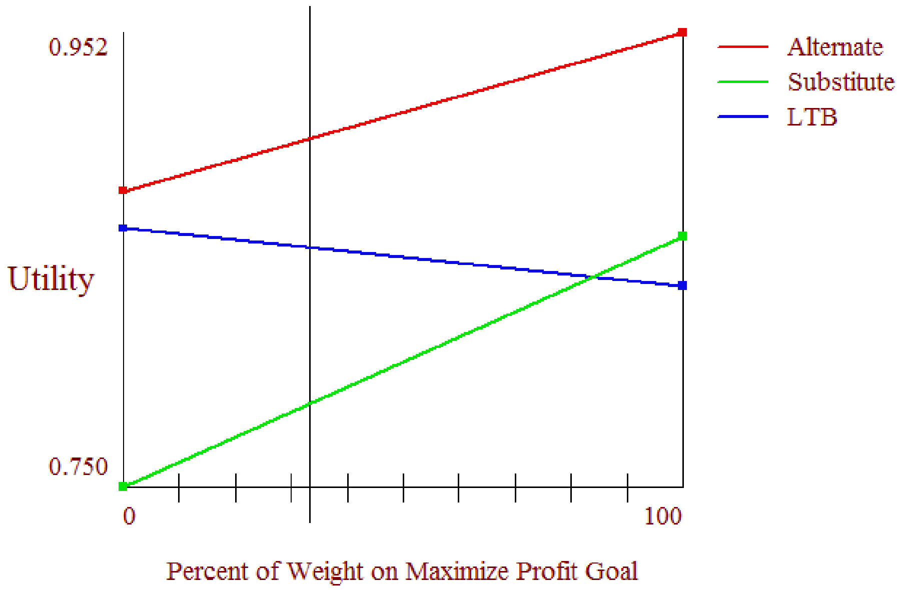

Figure 4-3 : Impact of change in weight assigned to profit goal on rank order

Figure 4-4 shows the impact of weight assigned to "functional upgrade" goal on the rank order, the rank order does not change with change in weight, so the rank order is not sensitive to the weight assigned to goal "functional upgrade".

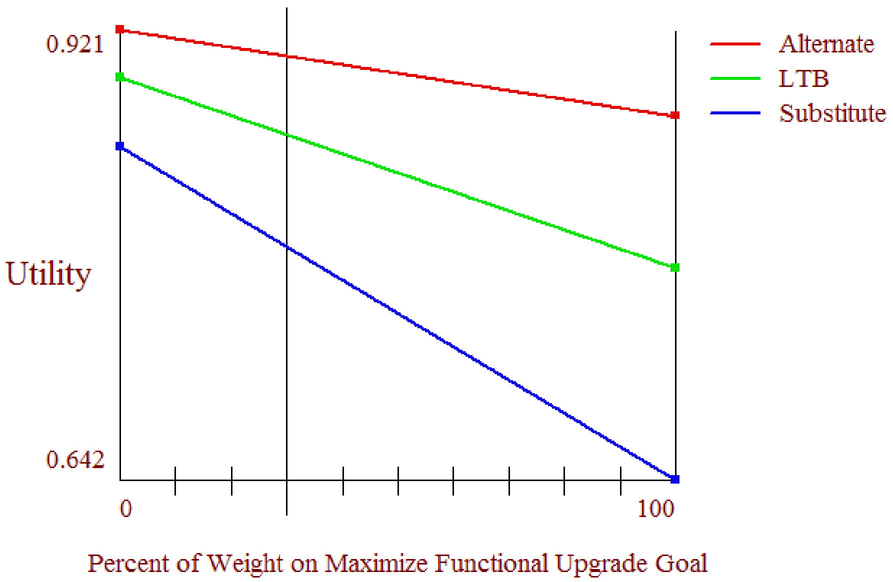

Figure 4-4 : Impact of change in weight assigned to functional upgrade goal on rank order

Figure 4-5 shows the impact of weight assigned to "supplier reliability" goal on the rank order. The current weight of supplier reliability is 0.2 and the rank order changes when weight on supplier reliability is just over 60%. This means that the rank order changes when the weight on supplier reliability changes by over 40%, which is a large value therefore it can be said that the rank order is not sensitive to the weight assigned to goal "supplier reliability".

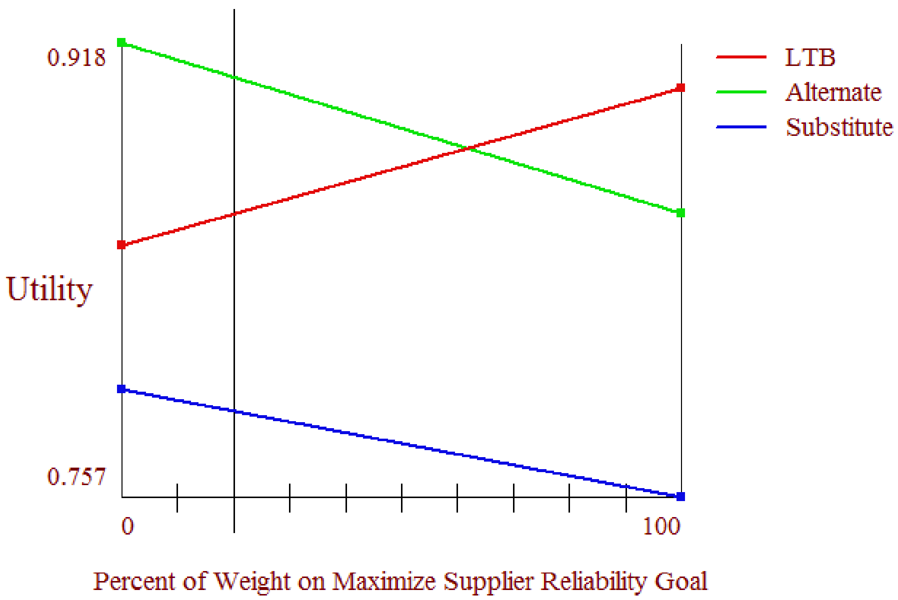

Figure 4-5 : Impact of change in weight assigned to supplier reliability goal on rank order

Figure 4-6 shows the impact of weight assigned to "implementation time" goal on the rank order. The current weight is just under 0.2 and the rank order changes when weight on supplier reliability is just over 50%. The rank order changes when the weight on supplier reliability changes by over 30%, which is a large value therefore it can be said that the rank order is not sensitive to the weight assigned to goal "implementation time".

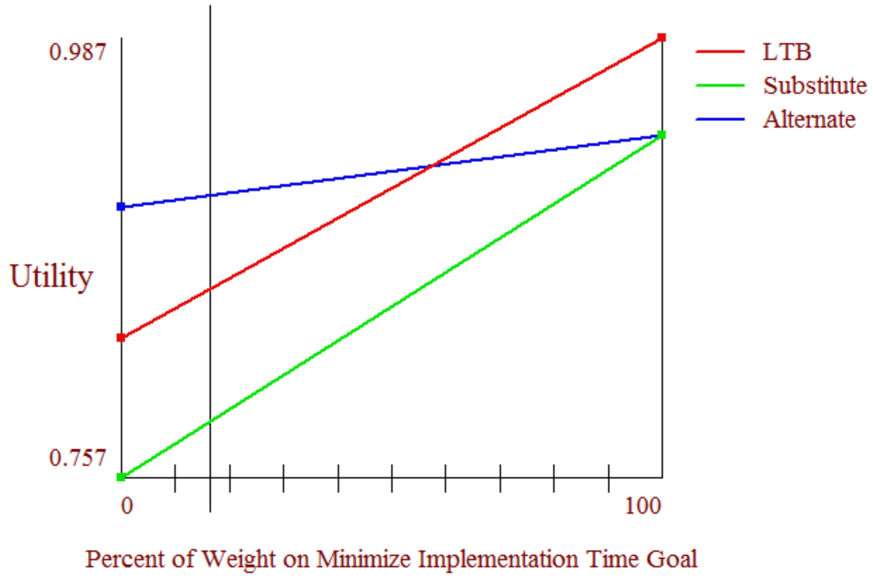

Figure 4-6 : Impact of change in weight assigned to goal time on rank order

Thus, from the sensitivity analysis it can be concluded that the result is not sensitive to the change in weight and the decision is robust.

4.2.3 Case 2

In this example the product is same, but the customer is a defense sector company, such that the demand is steady and is not affected much by performance improvement. The emphasis is more on the sustainable solution, so the importance of vendor reliability is higher compared to earlier case. This could be because there are stiff guidelines related to vendor authorizations and there are not enough suppliers authorized by the Department of Defense that can provide this part. The priority of the decision maker is to get reliable vendors, so that the risk of reoccurrence of obsolescence for the same part is low. Table 11 shows the expected values of cost, demand and selling price of the product.

Table 11 : Profit-cost matrix for the three strategies

	Substitute	LTB	Alternative
Forecasted demand until EOL of the product	7500	7500	7500
Selling price, $	480	480	490
Cost of this part, $	13.99	22.99	24.99
Implementation cost (per part) , $	6.50	1.20	8.50
Cost of other parts, $	400.00	400.00	400.00
Total cost, $	420.49	424.19	433.49
Profit, $	446325	418575	423825

4.2.3.1 Utility Values

Table 12 shows the attribute values for different measures for the three available parts, the most preferred, the least preferred attribute values for each measure and the attribute value of a measure at utility value of 0.5.

Table 12 : Attribute values for various measures

	Substitute	LTB	Alternative	Most preferred	Least preferred	attribute value at utility 0.5
Profit ($)	446,325	418,575	423,825	500,000	320,000	360,000
Memory size (GB)	2	4	4	8	1	-
Data rate (MT/s)	1600	1600	1866	1866	1333	-
Rating of the chosen supplier on a scale of 10	8	8.5	8	10	6.5	7.25
Number of suppliers	1	4	3	4	0	-
Time required for implementation (days)	55	30	55	21	70	60

Tables 13, 14 and 15 show the utility values for memory, data rate and the number of suppliers respectively.

Table 13 : Utility values for memory

Memory (GB)	1	2	4	8
utility value	0	0.5	0.8	1

Table 14 : Utility values for data rate

Data rate (MT/s)	1033	1333	1600	1866
utility value	0	0.5	0.8	1

Table 15 : Utility values for number of suppliers

Number of suppliers	0	1	2	3	4
utility value	0	0.5	0.75	0.85	1

Using equation 1 and Tables 12, 13, 14 and 15, the utility values of all the measures for the three strategies are calculated and are as shown in Table 16

Table 16 : Utility values for rest of the measures

	Substitute	LTB	Alternative
Profit	0.919	0.840	0.858
Memory size	0.500	0.750	0.750
Data rate	0.800	0.800	1.000
Rating of the chosen supplier	0.762	0.818	0.864
# Of suppliers available	0.750	1.000	0.850
Time required for implementation	0.651	0.987	0.651

4.2.3.2 Weights

Based on the discussion between various stakeholders and the decision maker (obsolescence management team) the rank order for the fundamental objectives are decided. Using swing weight methodology, as discussed in section 3.2.1.3 the final weights for fundamental objectives are assigned as shown in Table 17.

Table 17 : Weights for fundamental objectives (goals)

	Rank order	weights on a scale of 100	Normalized weight
Profit	1	100	0.32
Reliability of vendors	2	85	0.27
Functional upgrade	3	70	0.22
Time required for implementation	4	60	0.19

Similarly the weights for the means objectives for vendor reliability and functional upgrade are calculated as shown in Table 18.

The weights assigned to the fundamental objectives indicate that for this application the stakeholders and the decision maker have given the higher priority to reliability of vendors than profit.

Table 18 : Weights for means objectives

		Rank order	weights on a scale of 100	Normalized weight
Functional upgrade	Memory	1	100	0.53
	Data rate	2	90	0.47
Vendor reliability	Past performance score	1	100	0.54
	Number of suppliers	2	85	0.46

4.2.3.3 Result

Using equation (2) the weights and utility values of all the measures are aggregated and the final utility value of each strategy is calculated. The final rank order of strategies based on maximum utility value is created, as shown in Figure 4-7.

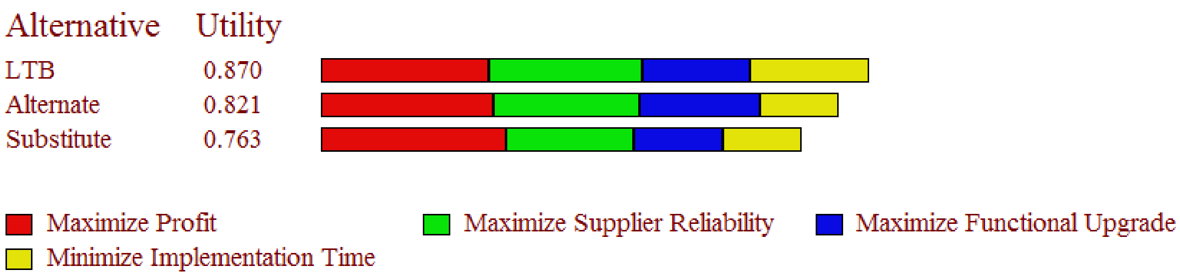

Figure 4-7 : Final rank order of strategies

The strategy with highest utility value is chosen, so for this case the most suitable ORS is "Life Time Buy".

4.2.3.4 Robustness of the result

Figures 4-8, 4-9, 4-10, 4-11 show the impact of change in weight of fundamental objectives (goals) on the rank order. The result is not sensitive to the change in weights of profit, functional upgrade and supplier reliability goal. However the result is sensitive to the weight assigned to implementation time goal, a reduction in weight by 15 % (approximately) may change the result to "alternate".

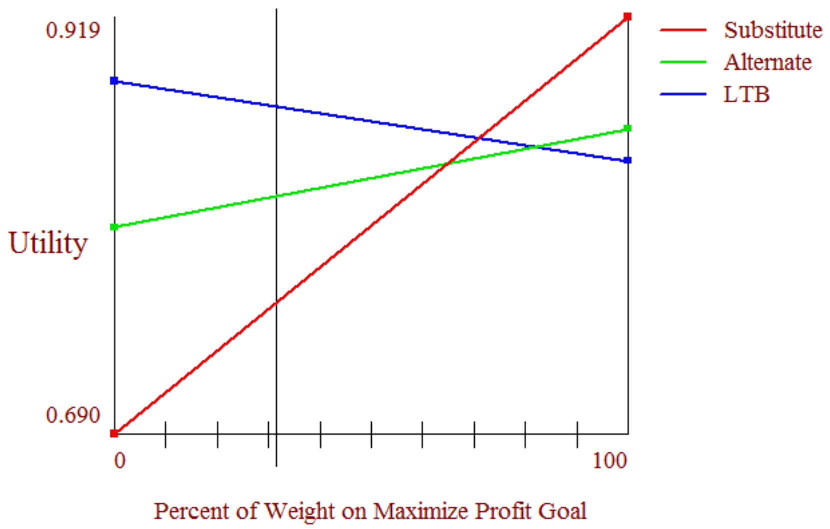

Figure 4-8 : Impact of change in weight assigned to profit goal on rank order

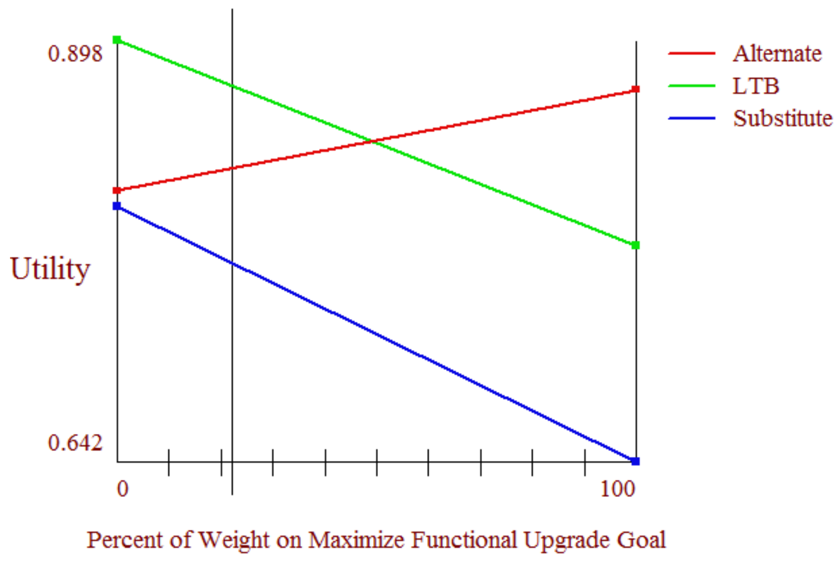

Figure 4-9 : Impact of change in weight assigned to profit goal on rank order

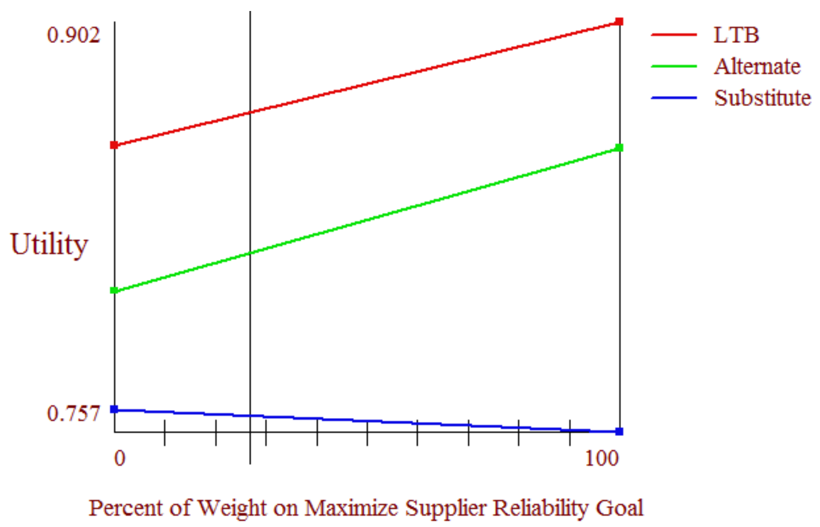

Figure 4-10 : Impact of change in weight assigned to profit goal on rank order

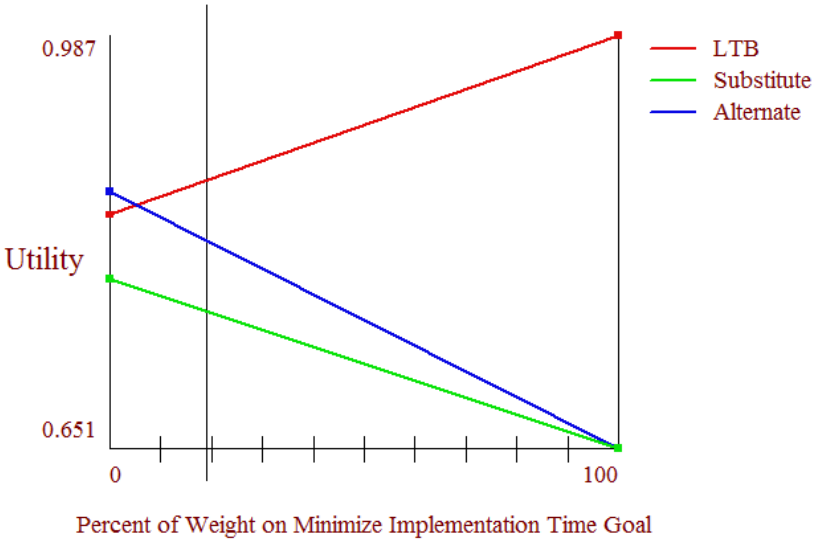

Figure 4-11 : Impact of change in weight assigned to profit goal on rank order

4.3 Conclusion

This chapter presents a generalized model using MAUT for selection of suitable Obsolescence Resolution Strategy. Then the chapter provides two distinct examples to demonstrate how to use MAUT for obsolescence management and shows how the inputs from stakeholders can affect the decision. The next chapter discusses the contribution, limitations and future scope of this research.

CHAPTER 5 : CONTRIBUTION AND FUTURE WORK

5.1 Research Summary

As discussed in Chapter 1, the objectives of this research are to identify the factors that need to be considered while choosing an obsolescence resolution strategy and create a decision model that accounts for subjective and quantitative factors and provide a suitable obsolescence resolution strategy. The research contribution can be categorized in three broad areas, which are discussed in sub-section 5.1.1 - 5.1.3.

5.1.1 Questions on Stakeholders

Q1. Who are the key stakeholders that may have impact on decision making in obsolescence management?

Q2. How does the opinion of various stakeholders affect the obsolescence management plan?

The research identifies some of the key stakeholders in the decision making process, which are:

1. Obsolescence management team
2. Manufacturing
3. Sales and marketing
4. Purchasing
5. Engineering / Design
6. Quality
7. Service

The research highlights the importance of these departments and briefly outlines how these departments can provide inputs to the decision maker. The involvement of stakeholders in the decision making process provides a diverse prospective and helps the decision maker to make a more informed decision. The case studies demonstrate how a similar problem may have different solution and how the knowledge and experience of stakeholders can play an important role in the decision making.

5.1.2 Questions on factors affecting decision making

Q1. What are the various factors that need to be considered while making a decision related to obsolescence management?

Q2. What is the relevance of these factors in the decision making process?

The research identifies some of the key factors that need to be considered while choosing a suitable ORS and highlights how these factors can affect the decision making process. The factors are:

1. Profit
2. Performance improvement/upgrade
3. Reliability of the vendors
4. Time required for implementation
5. Experience or views of stakeholders

The research highlights the importance of each of these factors in decision making. The case studies demonstrate how the emphasis on certain factors can change the decision.

5.1.3 Questions on Decision model

Q1. How to incorporate the qualitative factors, such as the opinions of stakeholders in the decision making process?

Q2. How to analyze the trade-offs between various factors that affect obsolescence management plan in the decision model?

The process of assigning weights to various measures in the MAUT framework gives the stakeholders an opportunity to contribute to the decision making. This process also allows the decision maker to manage the trade-offs of various factors.

5.2 Contributions of Research

The research has contributed in the field of decision making for obsolescence management. Chapters 3 and 4 provides a general framework and case studies of the proposed methodology.

The primary contribution of this research is that it lists various stakeholders and explains the importance of including the experience of stakeholders in the decision making process for obsolescence management. Secondly, the research lists some of the key factors that must be considered while choosing an ORS. The research clearly highlights that a decision cannot be made solely on the basis of least cost model, a holistic view of all the factors must be taken into account. Thirdly, the research proposes a decision model based on multi attribute utility theory that can consider subjective and quantitative factors to choose an ORS. The case studies demonstrate the application of the model in a hypothetical scenario.

5.3 Limitations and Future Work

The framework proposed in this research is a generic approach and the case studies are hypothetical scenarios. This research can be seen as a starting point in the direction of making informed decisions in the realm of obsolescence management. The factors affecting ORS discussed in this research provide only a few examples, ultimately factors will vary based on the requirements of the company, application area of the product and overall market strategy of the company. The approach is an added step in the current decision making process, however this methodology might give key insight into the factors that can really affect the decision, which otherwise would have been missed. The next stage of this research would be to prepare a comprehensive list of factors for specific industries or area of application that one should consider while choosing an ORS.

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APPENDIX A: SCORECARD METHODOLOGY FOR SUPPLIER EVALUATION

Figure A-1 shows an example for supplier evaluation. The vendors are given points based on various measures and the scores are given based on the importance of the measures. The final can be converted to a scale of 10.

Company Name/Logo

SUPPLIER RATING SCORE CARD

Supplier: **Assessment Period:**

RATING ELEMENT / PERSPECTIVE	RATING*	WEIGHT	SCORE	COMMENTS
Quality Performance				
• Material Acceptance (Conformance to requirements specified on Purchase Orders, Drawings, and associated Standards/Specifications)		X 7.0		
• Responsiveness to Issues (Timeliness & Effectiveness of Corrective Actions)		X 4.0		
(55 points max)		**Subtotal**		
Cost and Service Performance				
• Price Competitiveness & Value Added		X 1.0		
• On-Time Delivery		X 3.0		
• Lead Time & Cycle Time		X 1.0		
• Ease of Doing Business (i.e. Requesting Quotes, Placing Orders, Tracking Status, Flexibility, Response to Changes & other Requests)		X 1.0		
• Accuracy & Timeliness of Paperwork/Data (i.e. Quotes, Packing Slips, Invoices)		X 1.0		
(35 points max)		**Subtotal**		
Supplier Capability				
• Production Capability		X 1.0		
• Infrastructure (i.e. Quality, Manuf, Admin, Systems, Culture)		X 1.0		
(10 points max)		**Subtotal**		

(100 points max) **Total Earned Score** **Overall Rating**

QA Concurrence		Purchasing Concurrence		Production Control Concurrence		
*Ratings (as a % of max points)	1= Unacceptable 0-39%	2=Needs Improvement 40-59%	3=Average 60-79%	4=Above Average 80-89%	5=Excellent 90-100%	Rev. TBD MMDDYY

Figure A-1 : Scorecard method for supplier evaluation

APPENDIX B: OBJECTIVE HIERARCHY IN LOGICAL DECISION

Figure A-2 shows the objective hierarchy entered in “Logical Decisions”. The numerical values show the weights assigned (for case 1)

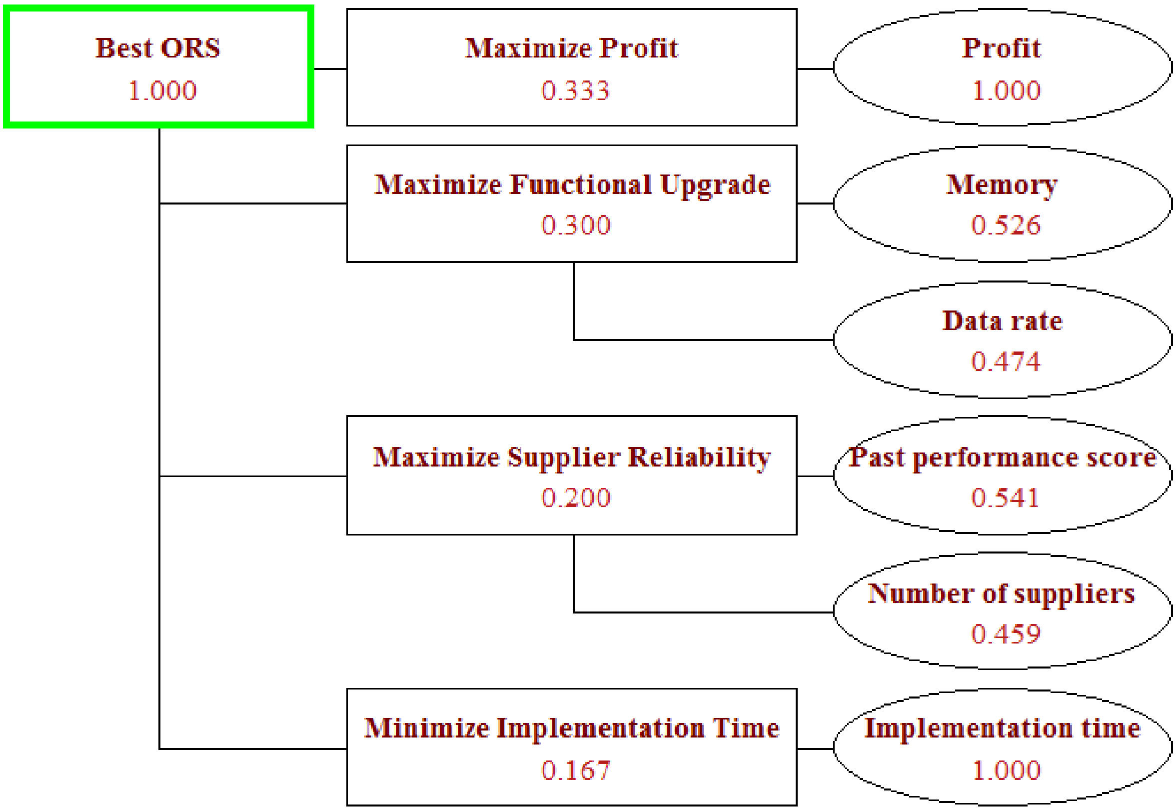

Figure A-2 : Objective hierarchy in “Logical Decisions”

APPENDIX C: RISK PREFERENCE OF THE DECISION MAKER

Figure A-3, A-4 and A-5 show the risk preferences of the decision maker for profit, past performance of supplier and implementation time measures respectively. The graphs show that the decision maker's choice preference is "risk averse".

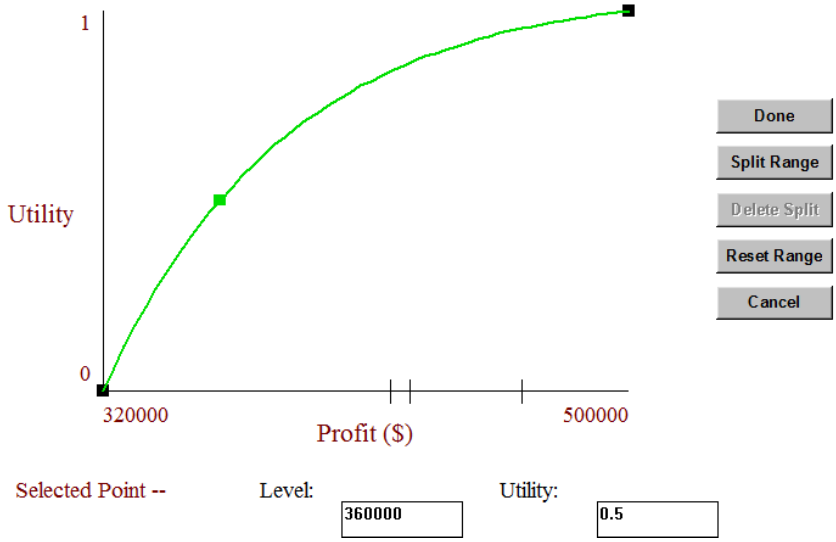

Figure A-3 : Risk preference for profit measure

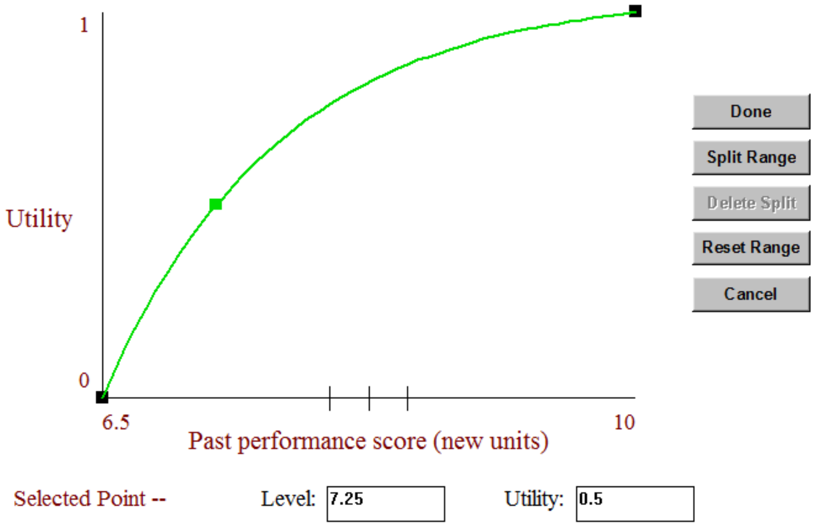

Figure A-4 : Risk preference for past performance of supplier measure

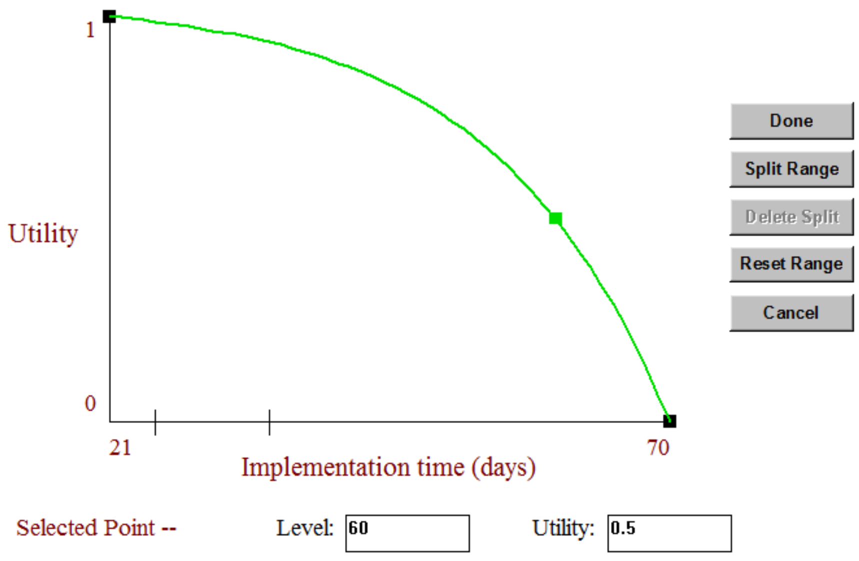

Figure A-5 : Risk preference for implementation time measure