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Obsolescence paths through the value chain

Amel Soltan[a,b], Sid-Ali Addouche[a] , Marc Zolghadri[a], Maher Barkallah[b], Mohamed Haddar[b]

[a] *Laboratoire Quartz, SUPMECA, 3 rue Fernand Hainaut, 93407, Saint-Ouen Cedex, France*
[b] *Ecole Nationale d'Ingénieurs de Sfax, Université de Sfax, L2MP, Route Soukra Km 3.5, BP 1173, 3038 Sfax, Tunisia*

Abstract

The obsolescence and diminishing manufacturing sources and material shortages, O/DMSMS in short, have consequences on the products architecture and on their desirability, usefulness, or usability. Different strategies are used to mitigate these risks. This paper relies on the possible sources of obsolescence for a focal company. The O/DMSMS could be originated within the company, its supply chain or its environment. The key idea is to explore the propagation of obsolescence and DMSMS throughout the product architecture and its supporting supply chain. By distinguishing obsolescence from DMSMS, it becomes possible to define solutions to deploy to reduce as much as possible their propagation, making the product and its supporting supply chain more resilient. These solutions are the barriers that can be subdivided into Design-for-Resilience and Control-for-Resilience. These concepts are discussed and illustrated through examples. Some conclusions and perspectives are discussed at the end of the paper.

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Keywords: Obsolescence; DMSMS ; System architecture ; Obsolescence propagation ; value chain

1. Introduction

Throughout its lifecycle, a product undergoes several changes to meet new customer requirements or to adapt its production to the more or less availability of materials and components. To remain competitive, companies accelerate the pace of the implemented changes. This reduces the life cycles of components. Therefore, new components appear, making the old ones obsolete. Obsolescence "refers to materials, parts, devices, software, services and processes that become non-procurable from their original manufacturer or supplier" [1] or according to [2] it deals with the process or condition by which a piece of equipment becomes no longer useful, or a form and function no longer current or available for production or repair. Diminishing Manufacturing Sources and Material Shortages, DMSMS in short, defined in [2] as "the loss, or impending loss, of manufacturers or suppliers of items, raw materials, or software".

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Authors in [3] highlight the difference and similarity between obsolescence and DMSMS. According to them "The obsolescence deals with characteristics of items while DMSMS focuses on the sourcing of items. DMSMS is a consequence of rarefaction while obsolescence is a consequence of uselessness". Even if these two concepts differ in some of their aspects, some of the techniques and methods to deal with them are similar [2]. "No system or program is immune from DMSMS" [2] and therefore to maintain and support long field-life products and systems, relevant management techniques should be implemented. Three kinds of obsolescence management are defined in [4]: reactive, proactive and strategic management. Reactive management deals with obsolete items providing answers to an upcoming obsolescence problem. Proactive management looks for predicting the obsolescence health of critical items and setting up resolution strategies while strategic management deals with reducing the obsolescence risks from the earliest design steps. O/DMSMS can affect components, functions (internal known by focal company) and functionalities (external known by users and customers). This papers looks to contribute to exploring the links between the product or system architecture and its supporting supply chain while dealing with O/DMSMS. It is argued that the obsolescence is mainly linked with the design of the product and therefore with its architecture, while the DMSMS is more focused on the manufacturing of the product and so with the supply chain. This could lead to define different solutions depending on the nature of the issued O/DMSMS. The sources of O/DMSMS can be internal (the focal company itself) or external (customer, supplier and environment). Each of these sources may affect the product architecture and its supporting supply chain. DS-22 [2] defines the first-order and derived obsolescence. A first-order obsolescence is directly driven by external forces while a derived obsolescence is functional obsolescence caused by changes made to address the first-order obsolescence. Therefore, O/DMSMS issues are propagated, as changes, from components to components or from functions to functions within the architecture. As a part of the components and functions of the product is delivered by suppliers, the supply chain will be impacted too in its turn by O/DMSMS issues. We can conclude therefore that from a given company point of view, called here the focal company (FC), we need to know the potential paths of obsolescence propagation to forecast the possible consequences of an O/DMSMS issue or to look for controlling it. Exploring the O/DMSMS propagation paths mechanisms is our main motivation.

2. Literature review

2.1. Obsolescence and Diminishing Manufacturing Sources and Material Shortages

From the definition of obsolescence in [5] it can be concluded that a component is considered obsolete when it no longer offers its services to customers at their expected performance. The obsolescence may touch the functionalities of the components of a product. It affects hardware and software. The reasons of the obsolescence are technology advancements [6], lack of support from vendors [6], merger and acquisition of a business [7] and incompatible product. The main solution to obsolescence is to reconsider the supply strategy of the obsolete component or function or to re-design the product. DMSMS is the (possible) interruption in supplying process throughout the value chain; it means that an offer is, or is becoming, rare. Dealing with rarefaction, the companies may adapt their manufacturing rate, supply sources or approaches, or even the product design. DMSMS is the output of the rarefaction process. This process is triggered by uncontrolled risks or natural disasters (e.g. earthquake [8]), accidents (e.g. fire 2015 [8]), the geopolitical instability (e.g. war [8]), or by controlled risks. These are essentially logistical problems like changes in transportation mode, port inspections at the border crossing, strikes and delays. In some cases, the unexpected increase of customer demands makes the company unable to satisfy these orders.

Table 1. Obsolescence and DMSMS

Phenomenon	Is concerned with	Models the
Obsolescence	Product/System characteristics, and architecture	Suitability
DMSMS	Supply chain characteristics, Manufacturing characteristics	Availability

This situation results in shortages that reduce the flow of materials through the supply chain. According to [9] "the obsolescence is the manifestation of two phenomena: (i) the item is no longer available from the OEM or (ii) the item

is no longer suitable for current demands". In our research we consider that DMSMS is the general term that define the second phenomenon while obsolescence refers to the first one, see Table.1

2.2. Mitigation strategies to obsolescence

Despite the distinction made in the last section, the research works refer to obsolescence management as a whole including simultaneously obsolescence and DMSMS. Mitigation strategies for obsolescence are classified into three categories. The reactive management addresses obsolescence by determining immediate solutions [10]: (i) the use of an existing stock or an alternative part, (ii) aftermarket, (iii) emulation, (iv) Life Time Buy and (v) redesign. But the cost of implementation of a reactive solution, in most cases, is high. Herald et al. have shown that to reduce the costs of solutions it is necessary to apply another type of mitigation approaches [11]. It is a proactive strategy which addresses obsolescence before it actually occurs by forecasting its costs and dates. So, one must find a good trade-off between cost and probability of obsolescence; if the probability is high, authors in [12] recommend to apply the reactive solution because it is faster. Otherwise, the costs must be minimized by choosing a proactive solution. Some of proactive approaches are to forecasting obsolescence, such as the approach developed in [13], which content 7 steps to determine the zone of obsolescence from the life cycle curve of a component. Other proactive approaches evaluate the risk of obsolescence like the practice proposed by Romero et al [14]. This method is called "Obsolescence risk assessment for the bill of materials (BoM)". Its important idea is to analyse the risk assessment process for each component in the BoM. The third management is strategic. It uses obsolescence data and demand forecasts to create a profitable long-term plan. The strategic approaches are: Material Risk Indices (MRI) and Design Refresh Planning [4]. We are focused on proactive strategies to model the obsolescence propagation paths from its source.

2.3. The considered supply chain

An O/DMSMS issue informs about the obsolescence or rarefaction. It is launched by a supplier, by a customer or by the FC itself. The consequences of an O/DMSMS issue can be propagated throughout the value chain if there is no way to deal with it locally. A supply chain is "a structured manufacturing process wherein raw materials are transformed into finished goods, then delivered to end customers" according to [15]. As reported in [16] a Supply Chain is the group of manufacturers, suppliers, distributors, retailers and transportation, information and other logistics management service that are engaged in providing goods to consumers. The Supply Chain adds value to a product from suppliers to customers throughout the whole process. To study the O/DMSMS possible propagation throughout the supply chain, we consider a generic part of a supply chain, containing a focal company for which we make the study, its direct customers and suppliers. This network deals with products delivery to the customers. A product can be studied from two points of view: internal and external. Internally, the FC designs and manufactures the product. The product architecture is known by FC. External actors group customers, suppliers and all other stakeholders that form the FC's environment. They do not fully know the product architecture.

The O/DMSMS may be sourced from any of these four classes of actors of the product: the FC itself, its customers, its suppliers or its environment. Any O/DMSMS generated could be propagated back and forth throughout the supply chain. Let us clarify this idea. Suppose that micro-chips are provided by a supplier S to FC which designs and produces dashboards for a customer, a car maker R. Suppose also that the car maker notifies that its buyers or consumers do need an upgraded dashboard containing a computer screen. If the dashboard is designed and made by the FC, the obsolescence issue generated by the car maker becomes a design issue for the FC. In its turn, the FC may need to renew the requirements of the some microchips provided by its supplier S, if it does not have the ability to deal with this obsolescence issue locally. The obsolescence is then propagated step by step upward the supply chain depending on the capacity of each level to "absorb" the new requirements. It can be understood therefore that the obsolescence issue impacts the car, dashboard, and component architecture but also at the same time, it is propagated along the supply chain. The product architecture defines then the patterns of O/DMSMS issue propagation throughout the supply chain. We focus then on the possible propagation paths throughout the X supply chain surrounding the FC. If these propagation paths are properly identified, solutions may be set up to control (to stop or to limit) the propagation of their consequences.

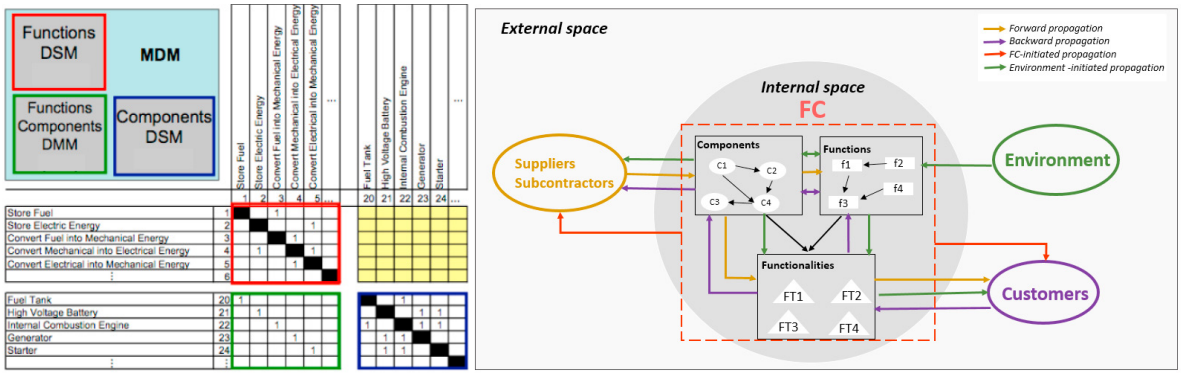

Fig 1: System architecture (MDM) [14] and Obsolescence propagation paths

3. Product architecture

Ulrich defines the product architecture in [17] as "The scheme by which the functions of a product are allocated to physical components". In other words, a system is an interconnected set of components and functions. This set gives a series of functionalities to meet the customers' requirements. The architecture informs about the components of the product, the elementary functions of each component and the functionalities offered to users, but also somehow the way these components work together and on the way they are built, used and assembled. A system has a physical structure composed as a hierarchy of components. Components are defined by a set of attributes (weight, dimension…). The components perform functions that are the transformations that contribute to the overall performance of the product [19]. The mapping function-component defines the functionality to satisfy the consumer requirements. The set of functionalities (ϕ) is the third element of the system architecture. To represent the interaction between these three classes of elements we can use the Design Structure Matrix (DSM) [20]. It represents the dependency of the elements in the same domain, see Figure 1. It is possible to represent the relationships between elements which belong to two different domains by using the Domain Mapping Matrix (DMM) [21]. To represent the dependencies within a product we use two DSM and one DMM. The first DSM represent the dependency between components and the other represents the dependency between functions. The DMM is used to know the mapping between functions and components. To represent the system architecture, Gorbea et al. [22] proposed another matrix MDM (Multiple Domain Matrix) which is the fusion of DMM and DSM.

4. Obsolescence/DMSMS propagation

The external space of the product (customers, suppliers and environment) affects the product. As a result, there are four obsolescence propagation paths within the supply chain, represented in Figure 1-right.

Forward propagation. Suppliers supply FC with specified raw materials and components with precise quantities and frequencies. Changes in the technical requirements of the supplies may impact the FC which could transfer it to its customers if it is not able to cope with it locally. This is also the same for the DMSMS issue because any rarefaction of the supplies would impact the downward actors. These are forward propagations.

Illustrative example. If the supplier S of the micro-chips modify their attributes (e.g. footprint), the FC's dashboard technical specifications may be modified leading to the propagation to the car maker R (even if very often, the focal company is not allowed to modify these technical specifications due to contractual obligations).

Backward propagation. Customers see the functionalities offered by the product and are also concerned by the components attributes, functions performances, they can pose constraints on suppliers. They can be the source of O/DMSMS by considering a functionality as obsolete. As the functionalities are the mapping between the physical structure and functions, this functionality obsolescence issue affects the FC, which in turn may be propagated it to suppliers. This is backward propagation; an O/DMSMS issue goes from the customer-side to the supplier-side.

Illustrative example. If the car maker R needs a LCD screen in the dashboard, the FC has to renew the dashboard

design, asking for modifications to supplier S (e.g. higher performance micro-chip).

FC-initiated propagation. FC could innovate and modify either the components and/or functions of its products. In this case, the changes in the architecture would reach the customer. These changes may also involve that FC asks for changes in the components provided by the supplier too.

Illustrative example. If FC makes evolve the dashboard by integrating a touchscreen, rendering the last dashboard obsolete the car maker R should deal with this interruption either by making an LBO (Last Buy Order) for instance or by integrating the new dashboard in the interior design of the cars. The supplier S may also be impacted because the used micro-chips are not relevant to the new dashboard.

Environment-initiated propagation. The environment imposes constraints on the design, manufacturing use and recycling through for instance international or national regulations (such as the rate of gas released, etc.). Such O/DMSMS can affect all the actors of the value chain (suppliers, FC, customers). In this case, we can have any of the three propagation paths (Forward, Backward and FC-initiated propagations).

Illustrative example. Recycling rules imposed by standards may be applied to the car maker R limiting the use of certain materials. This could be transformed into new specifications for the FC and the materials used in the dashboard.

5. Barriers surrounding the O/DMSMS

To simplify the study, we eliminate the Environment-initiated propagation and we keep the propagations paths through the value chain. We classify the propagations in two group; a group caused by the obsolescence which contains Forward, Backward and FC-initiated propagations. These propagations affect the system architecture. The second group is caused by the DMSMS which contains only the Forward propagation because there are due to the problems in components supply. After determining the different possible obsolescence propagation paths, the question now is to limit these propagations? In other words, can we put in place barriers to cut off these propagations? Since the propagations are caused either by the obsolescence or by the DMSMS, two type of barriers may be distinguished: technical and manufacturing barriers. A barrier is a solution that allows to deal with the O/DMSMS issue locally or it reduces the potential consequences impeaching their propagation in any direction.

5.1. Technical barrier: a solution to obsolescence issue

The obsolescence touches the characteristics of the component [3] (functions, components). The technical barriers are the modifications in the system architecture obtained during the design phase to make the system as resilient as possible to O/DMSMS. We call this design activity Design-For-Resilience. Let us now model the architecture of a product by extending the suggested representation by [23] in figure.2. The internal and external views of the product are separated by the vertical red lines on the left-side figure. Each box represents a matrix. C/C, F/F and C/F are the matrices that model respectively the components and functional linkage, and the mapping between the components and functions. Together they define the product architecture. The components are provided by the supply side of the supply chain, modelled by SC/C. SC/SC shows the suppliers' interdependencies, if any. They could be explicit and imposed by FC. In all cases, these dependencies do exist even implicitly through the C/C linkage. The analysis of the product architecture may lead the FC to associate some suppliers with the required functions of the products. This could be the case of associating a given supplier to the function "regulated AC/DC transformation". These relations are modelled through the matrix SC-F. The functions are used to perform some functionalities awaited by the customer, modelled by F/ϕ. The functionalities inter-dependencies are modelled by ϕ/ϕ. This is the case of having access to "high fidelity audio function" and "high speed MP3 conversion"; two functionalities for final consumers of the car. Based on the internal analysis of the company, it would be possible to map the awaited functionalities of the customers to the internal structure of the product through C/ϕ. Finally, it becomes possible to link the customers' functionalities to suppliers through SC/ϕ. It is then possible to forecast any possible modifications in the supply side of the supply chain studying functionalities new requirements asked by customers. Even if these matrices are not all available, exploring the domains and inter-domains dependencies and linkage allow to navigate through this model. All these matrices are the adjacency matrices and can be transformed into graphs for any algorithmic usage. Defined as this, the whole interconnected model is called here the product/supply chain linkage model.

Dealing with obsolescence, the FC should use the technical barriers. We define the technical barriers as those

techniques (technological or not) that allow to control or to minimize the propagation of the obsolescence throughout the product architecture or outside the focal company. The red lines in the left-side hand model in Figure 3 show the possible technical barriers that can be put in order to limit the obsolescence propagation. The black arrows show various possible impacts of any obsolescence issue generated from the customer, supplier or FC.

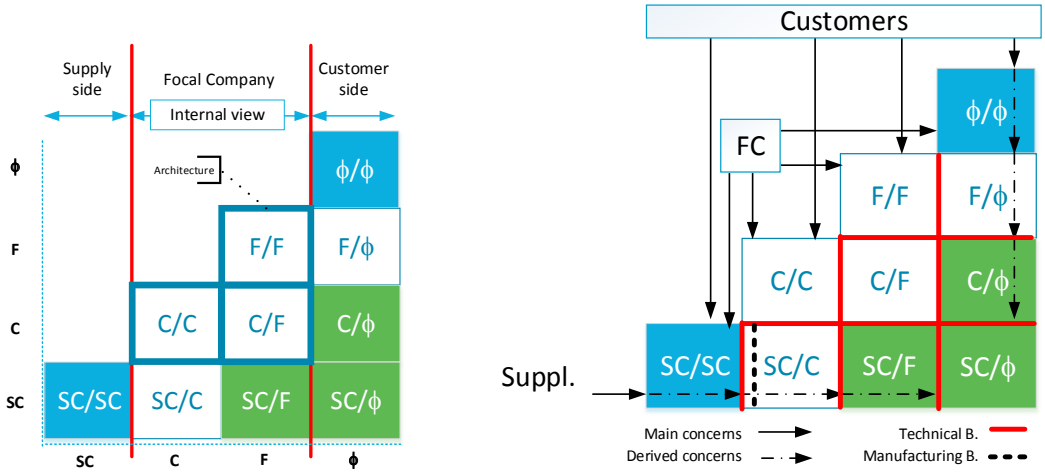

Fig 3: O/DMSMS propagation through the product and supply chain architectures

In F/ϕ, F/F, C/F, C/C the goal is to limit as much as possible the coupling in functions, functions/functionalities, components/functions, and components/functions. This is to design the product in such a way that the linkage matrices be diagonal as much as possible. In the context of SC/C during the design, the idea is to coordinate suppliers inputs with the global product design strategies defined, see table 2.

Figure 4 shows an illustration of the technical barriers used during the design of the product. If an obsolescence issue is launched for the components c2, the potential use of C/F and F/ϕ would allow to deal with it locally preventing the obsolescence propagation to customer. Four possible solutions are presented here; the best one should be determined to find out cost and efficiency tradeoffs.

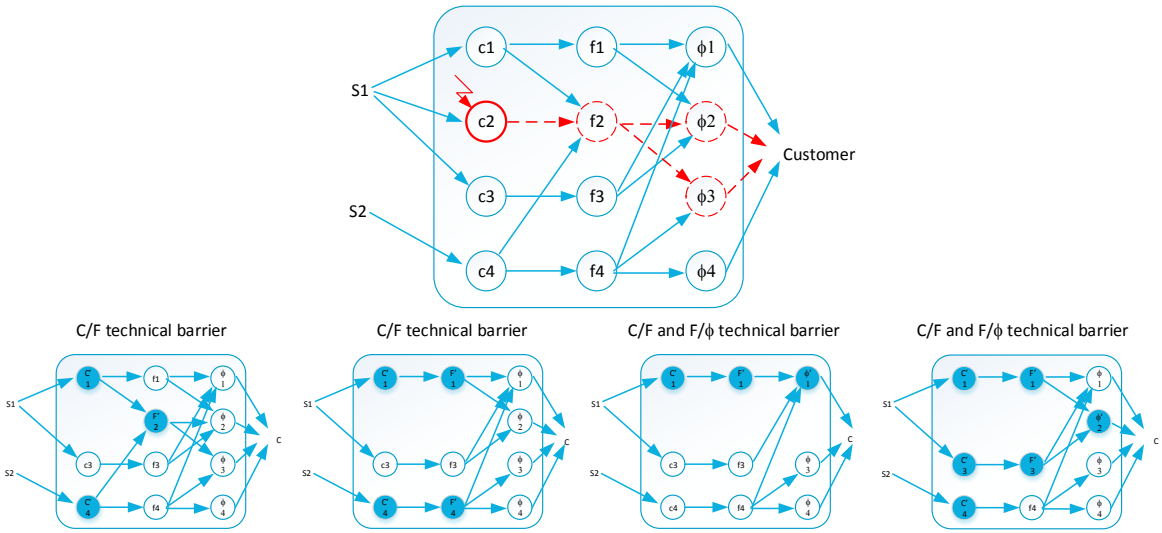

Figure 4: Illustration of technical barriers within the product architecture

Table 2: Technical barriers

Technical barriers	Definition	Role in O/DMSMS	Advantages	disadvantages
Modularisation	The modularisation is the activity in which a complex product is decomposed into blocks or sets of components [26] called 'modules'[27].	Independent components, linked, by standard interfaces. If the obsolescence affects one of these sets, just replace it by another one without affecting the architecture.	- Product flexibility -Wide variety -Reuse, -Easier project mgt -Facilitate product recycling [27]	-The more we use modules in a product, the more its performance is affected [27] -A loss of brand identity -Making a product heavier [27]
Standardisation	"Determining regulations for general and multiple uses, with regard to real or potential problems, so as to obtain optimal arrangement level in the given context" [28], [29]	Standard interfaces stops the obsolescence propagation. The obsolete component is replaced without causing negative effects on the system thanks to this interface.	-Facilitate the exchange of products and services. -Develop cooperation in several fields [30]. -Create common understanding	-Time consuming. -Delay in TTM [30]. -Could limit creativity and the innovation [30].
Commonalities	The commonality is the use, more than one, of the same part/component in different locations of a final product. [31]	Their use of reduces TTM, accelerates the introduction of new technologies and responds to the new customer requirements. It minimizes the risk of the obsolescence comes from FC and from the customer.	-Reduce the inventory level -Improve flexibility -Decrease the set-up time and increase productivity -Simplify the planning and scheduling -Decrease lead-time [32].	-The commonalities require an over-specific and over-dimensioned [33]. -The use of the same component leads to the brand distortion on a product.
Customization	The customization is the design of a product based on customers' needs and requirements. It increases the flexibility of the production [29].	It can be a strong technical barrier to the obsolescence comes from the customers.	-Sales increase [29]. -Creating higher intimacy between FC and customers.	Demand changes affect the production subsystems, require engagement of the engineering activities to translate the demands to functions and structures [29].

5.2. Manufacturing barrier: a solution to DMSMS issue

Through the value chain, there may be discontinuities in the supply of the component caused by the DMSMS. The sources of the DMSMS are multiple as mentioned in section 2. The manufacturing barrier is about building greater resilience into the supply chain rarefaction process. These manufacturing barriers allow to limit the effects of rarefaction and called here the techniques of Control-For-Resilience. They are related to the SC-C elementary path. The most effective supply chain risk mitigation strategies are presented in the following.

Multi-sourcing: It reduces the dependence on single supply source and using dual or multiple sourcing [24].

Active inventory tracking: The FC must adopt an optimized and smart management of inventory levels to avoid the unexpended increase of the customer demands.

Alternatives for distribution and transport: When the FC meets many logistical problems, it is necessary to have other alternatives for transport or distribution to ensure the satisfaction of the customer at the expected time and place.

Cooperation: The elements of the value chain should exchange and share different data and information about the actual situation. This can be a useful solution to anticipate or reduce the unexpected risks. For example, a company that has the risk of losing a critical supplier must inform its customers to find solutions to minimize the costs generated by this change.

Supply chain risk management (SCRM): the SCRM culture is an important means to mitigate the risks through the value chain. According to Artebrant, the SCRM is " the identification and management of risks within the supply chain and risks external to it through a coordinated approach amongst supply chain members in order to reduce supply chain vulnerability as a whole"[25].

6. Conclusions

Engineering product/system design changes are necessary to follow the advances in technology and to provide innovative solutions to keep the company competitive advantage. Consequently, these changes affect the component's lifecycle and it becomes shorter than the product's life cycle that contains this component. This is the root of the

product obsolescence. While obsolescence deals with the suitability of components, DMSMS faces the availability of components. The O/DMSMS issues are propagated in the product architecture and the supporting supply chain. If it is not well managed, the O/DMSMS will cause excessive costs and serious problems throughout the supply chain. To limit the risks generated by O/DMSMS several mitigation approaches are used. This paper addresses the O/DMSMS propagation paths mechanisms through the value chain and architecture. We looked at identifying the main propagation paths within the supply chain and link them to the product architecture. The possible solutions to mitigate these risks are gathered into two types of barriers: a technical barrier and a manufacturing barrier. The first barrier touches the system architecture and serves to surround the obsolescence comes from the customer and FC. The second barrier is founded to create different solutions to the DMSMS.

Defining the dependencies by various matrices allows to transform them into graphs. We use the Bayesian approach to evaluate the risks or obsolescence throughout the supply chain and the product architecture. The ongoing research works are focused on the risk evaluations through probabilities and attributes such as costs.

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