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# Despecialization: a systematic approach to (re-)engineer systems ensuring a better resilience to obsolescence and shortages

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## Abstract

Obsolescence and shortages have a strong impact on all value chains today. They can be found in all areas. They have an impact on both consumers and manufacturers. They can affect all components, products, systems, etc. Facing these two phenomena, ABMI, a multi-specialty engineering company, proposes despecialization as a solution. It allows components to be remanufactured and upgraded without the original supplier's specifications in case of obsolescence or shortage. This despecialization generally makes the system more resilient and robust. However, when despecialization is carried out to address obsolescence and shortages, different sets of consequences may arise. The improvements made to one component may, for example, degrade the performance of certain functions, or they may change the behavior of other components, or even change the properties of the system, i.e. reliability, maintainability, and availability. All these changes are the result of the propagation of the consequences of obsolescence and shortages. It is therefore essential to study the dependencies, especially between components, in any despecialization action to ensure the proper functioning of the system and its sustainability over time. In this paper, certain dependencies are studied in a case study of a mechanical system. We use Bayesian network theory to explore the modeled dependencies. The objective is to show the propagation of the effects of architectural changes on the resilience of the redesigned or despecialized product. The paper concluded with conclusions and perspectives on future research undertaken.

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**Keywords:** Despecialization; Obsolescence; Resiliency; Dependencies; Bayesian Network.

## 1. Introduction

Obsolescence refers to the process by which a product, technology, or service becomes obsolete or no longer useful. This can happen for a variety of reasons, including technological advances, changing market conditions, or the unavailability of spare parts or technical knowledge to repair a product. In some cases, obsolescence is a natural process that occurs over time, while in other cases it is artificially induced by a company to encourage consumers to buy newer products. Obsolescence can have significant economic and social implications, as it can lead to the replacement of products that still work properly and the generation of e-waste. It can also have ethical and moral implications, as it can lead to the unnecessary consumption of resources and the creation of waste. To address this obsolescence, ABMI, a multi-specialty engineering company, offers despecialization as a solution. Despecialization allows components

to be redesigned while improving the resilience and robustness factor. As a result, the despecialized component will in some cases be more resilient and robust than the previous one. Sometimes the improvements made to some components after despecialization can have a negative impact on the other components and make the system less resilient and robust. In this paper, we will study the propagation of its resilience effects on the other components and prove that the despecialization proposed by ABMI company ensures a more resilient system/product than the old obsolete system/product. To carry out this study one must know the initial architecture of the component and understand the system. Once the study of the existing system is completed and the Obsolescence/Shortages Cause, Effects, and Criticality Analysis (OSCECA) is done, the new version of the despecialized and improved component is proposed. We analyze different dependencies between different components and build the Bayesian network (BN). The BN will be analyzed and inference scenarios will be performed to study the propagation

of resilience effects of a component on other components before and after despecialization. In this paper, the methodology for despecialization will be detailed. In order to validate this methodology, we will apply it to one of the projects on which ABMI has already worked namely the quadrant jockey wheel.

This paper is articulated as follows. In section 2, the obsolescence problem, the concept of resilience, the despecialization of components, and a BN approach are described. In section 3, the various cases of resilience will be studied and the despecialization methodology we have established will be developed. Section 4 will use the case study of the quadrant jockey wheel to validate the methodology. A comparative study will also be conducted in this section. In Section 5, the paper concludes by presenting future research.

## 2. Related works

A complex system is defined as a set of subsystems of different natures with many non-trivial interactions. The system is dynamic and incorporates human and organizational factors. Some components of the system may become rare or obsolete, leading ultimately to the obsolescence of the system itself. In order to keep the system operational, it may be necessary to partially redesign it. Despecialization is a redesign approach developed by ABMI. Its objective is to make the system more resilient and therefore more sustainable over time. This durability does not mean that the product will not fail, but that it will better resist disruptions generated by obsolescence or shortages while recovering its functions more quickly.

### 2.1. Obsolescence/Shortage of components

According to [1], obsolescence is the transition from the state of availability to the state of unavailability of an entity from its manufacturer according to the original specification. While a Diminishing Manufacturing Sources and Material Shortages (DMSMS) or Rarefaction/shortage is defined as "the loss or the impending loss of manufacturers or suppliers of items, raw materials or software" according to the SD-22 Guidebook [2]. Then, according to [3], obsolescence refers to the inadequacy of an entity to needs, expectations, or requirements, while shortage refers to the unavailability or rarefaction of sources or resources. Obsolescence and shortages are inevitable and can have serious economic or environmental consequences for all actors in the value chain. To counter obsolescence/shortage, [4] proposes three management modes. There is reactive management which consists of making decisions when obsolescence has already occurred. There is also proactive management, which is implemented for critical components with a risk of obsolescence. And the last one is strategic management which involves determining the optimal combination of mitigation and design update approaches using data from forecasts, logistics, and obsolescence dates. In the case study reported here, we deal with a reactive management case.

### 2.2. Resilience of components

In the field of engineering, there are various definitions of resilience. The Oxford Dictionary defines it as "the ability to recover quickly from difficulties". According to [5], resilience is the ability to resist, absorb, recover, or adapt to challenge or change. While author in [6] considers resilience as the capacity of a system to anticipate, survive and recover from stress caused by a threatening situation. It is also defined by [7] as the ability of a system to recover from losses in value induced by disturbances within an allowed recovery time. [8] proposes a complete definition compared to other authors and defines it as the ability to anticipate, prepare for, respond to, adapt to, and mitigate the consequences of disruptions, as well as to recover quickly and effectively, including through restoration, preservation of services. In summary, resilience covers the capacities of anticipation, survival, and recovery and is described by the three indicators: reliability, robustness, and restorability, which are referred to as the three resilience pillars [9].

### 2.3. Despecialization

Despecialization is a term originated by ABMI to differentiate itself from existing methods. It translates into reverse engineering [10], also known as retro engineering, including the increased resilience of redesigned systems. It is the process of disassembling and analyzing a product or system in order to understand its design, construction, and operation. Despecialization can be used to reverse engineer a wide variety of products, including electronic devices, mechanical systems, software, and chemical compounds. It is often used to analyze and improve existing products, or to develop new products from existing designs. Despecialization can also be used to reverse engineer products that are no longer supported or have become obsolete, in order to extend their life or to repair them.

### 2.4. Bayesian networks

A Bayesian Network (BN) is a directed acyclic graph (DAG) [11]. It is a combination of graph theory and probability theory and is presented in the form of nodes interconnected by directed arcs. Each node has a set of mutually exclusive states and an a priori or Conditional Probabilities Table (CPT). BN represents the conditional dependencies between the different nodes of the network and essentially traces the propagation of events [12]. According to [13], a BN is a way to represent the knowledge of a system. Its representation is carried out, depending on the context, with the aim of predict the behavior of the system, diagnose the causes of a phenomenon observed in the system, control the behavior of the system, simulate the behavior of the system, analyze data about the system and making decisions about the system. In this paper, we will use a BN as a tool to simulate the behavior of the system and to study the propagation of events between nodes.

### 3. The defined methodology

An obsolete system or product may be in a functional or non-functional state. When it is functional, it may be in a good state or in a degraded mode. If a major failure affects a function or component preventing the system or product from carrying out its function(s), it is non-functional. Despecialization occurs for products or systems in degraded or non-functional mode. Table 1 summarises these different states.

Table 1. Health states of an obsolete system/product.

		Possible states	
		Functional	Non-functional
Possible sub-states	Good state		
	Degraded mode	Despecialization	
	Failure		Despecialization

Faced with a disturbance (obsolescence, shortage, etc.) that a product or system may experience, it may react in different ways. To explain this, different possible cases have been studied and illustrated by curves which are described in Fig. 1. Two parameters have been mentioned in these curves which are: (i) Recovery time is the time needed for the system to resume its operation once it has emerged from its minimal initial state. (ii) Degradation depth which gives an idea of the severity of the disruption that has occurred. The greater the depth, the more severe and profound the disruption.

- Curve 1 Non-resilient and out-of-service system: following a disturbance, the state of the system has degraded until it comes to a complete stop. The depth of degradation is very significant and there is no recovery time.
- Curve 2 Non-resilient and non-performing system: following a disturbance, the system state degrades and falls below the minimum threshold of acceptability for normal system operation. The depth of degradation and the recovery time are important.
- Curve 3 Resilient, Globally Less Performing GLP and not robust System: Here, the operating state of the system degrades while remaining resilient in terms of not exceeding the minimum threshold of acceptability and creating a new operating interval less performing than its initial operation. The depth of the degradation is considerable and the recovery time depends on the duration of the despecialization operations.
- Curve 4 Resilient and Globally at Least Equivalent GLE System: In the face of a disturbance, the system degrades without exceeding the minimum acceptability threshold. It then resumes its operation more or less equivalent to its initial operation. The depth of degradation is not important and the recovery time depends on the duration of the despecialization operations.
- Curve 5 Robust system: After a disturbance, the performance or operation of the system degrades while remaining within the normal operating range. In this case, degradation depth and recovery time cannot be specified.

- Curve 6 Resilient and Globally Better Performing GBP system: In response to a disturbance, the system degrades without exceeding the minimum acceptability threshold. It then resumes operation with increased performance due to improvements in the system. This creates a better acceptability range (of performance and attributes) which is that of the old operation. The depth of degradation may not be significant. The recovery time depends on the duration of the despecialization operations.

Despecialization occurs in the last four curve cases mentioned.

In order to prove that a system/component is resilient and/or performs better following despecialization, it is necessary to study the system/component before and after despecialization and then compare the results. To do this, it was decided to use BNs to study the dependencies between components, and the methodology shown in the following Fig. 3 was developed.

In the despecialization part, to begin with, the initial architecture of the system and its analysis of the Obsolescence/Shortage Cause, Effects, and Criticality Analysis (OSCECA) are established (see the article by [14] which proposes an FMEA-like method for the management of obsolescence). Then and from the OSCECA obtained, one carries out a despecialization obtained thanks to the application of the techniques of reduction or suppression of the dependencies within the architecture:

- Reducing dependency, i.e. reducing the impact or influence of one component on another component via the choice of materials, type of assembly, modification of the top-level component in the BOM, or generic components that can adapt to different needs (e.g. the use of FPGA components instead of specific components).
- Remove dependency between components.

We then proceed to establish the new architecture of our system/component after despecialization and implement its new OSCECA.

### 4. Case study and discussion

The case study is a project involving the jockey wheel quadrant of a trailer. The quadrant in Fig. 3.(a) is the central part of a one-tonne trailer that allows the jockey wheel to be tilted into the park or road position. It consists of three components: a left roof with an end-stop, a right roof, and an axis. These components are assembled and mechanically welded.

In use, the jockey wheel quadrant can be subjected to shocks and vibrations by its positioning or by the movements of the trailer. In the long term, certain structural failures will occur in the dial. The part that degrades fastest and makes the part obsolete is the end-stop. This is part of the left roof. In fact, it is bound to deform or break when the jockey wheel is used. The type of jockey wheel discussed here is nowadays obsolete and is no longer manufactured and sold on the market. Nevertheless,



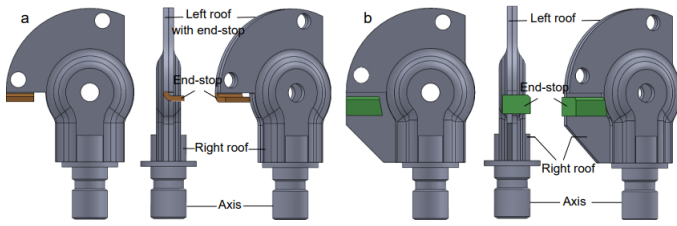


Fig. 3. (a) Original jockey wheel quadrant; (b) Upgraded version of the jockey wheel quadrant after despecialization.

the customer wishes to keep and maintain the use of jockey wheels on his trailers. Hence the need to despecialize this part. The final objective here is to prove : (1) The respect of the functional requirements expected of the part with the proposed definition, (2) The non-regression of the technical and operational performances, (3) The absence of safety impact in static terms, and (4) No impact on the safety of goods and people.

In order to analyze the obsolescence and shortage of the parts forming the quadrant of the jockey wheel, an OSCECA was developed. This tool allowed to set up of the following corrective actions which will be applied to remedy the problem of the deformation and breakage of the end-stop:

- Modify the geometry of the stamped roof to which the end-stop is attached
- Thicken the end-stop and modify its geometry to make it more resistant
- Weld the end-stop to the stamped roof

Taking into account these actions and after several simulations to prove the robustness of the new product (we will not detail this part as it is not our objective in this paper), the despecialization study allowed us to manufacture a quadrant of the jockey wheel more resilient and Globally Better Performing GBP than the original dial (see Fig. 3.(b)).

This newly designed quadrant is marked by the separation of the end-stop from the left roof, making it thicker with a change in its geometry. Finally, it is welded on all four sides with the two roofs.

After simulations, it was shown that the quadrant after despecialization is more resilient than the original one. The question that is asked here is whether the despecialization of the end-stop has no impact on the other components of the quadrant? or what is the impact of the propagation of the resilience of the end-stop on the other components? To answer these questions, we used a BN. The initial system architecture shown in Fig. 3.(a) was modeled by a BN in Fig. 4.(a).

This structure shows that the quadrant depends on the axis, the right roof, and the left roof with the end-stop, and that the latter influences all the other components. In other words, when there is a failure or breakdown in the left roof with the end-stop, its effect will be propagated to the other components, i.e. the quadrant, the right roof, and the axis, and their condition will deteriorate. After despecialization, the quadrant of the jockey wheel underwent changes and improvements as explained ear-

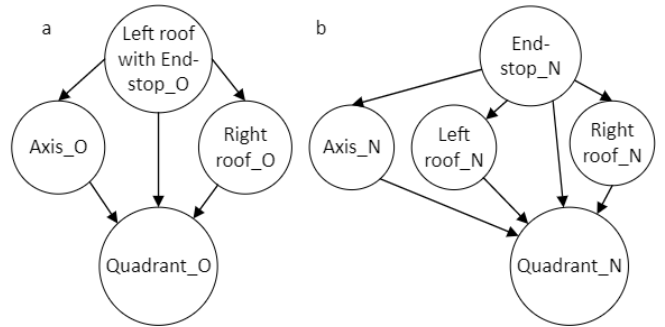


Fig. 4. (a) Initial Bayesian network of the jockey wheel quadrant; (b) Bayesian network of the jockey wheel quadrant after despecialization.

lier. Subsequently, the structure of the original BN changed to another structure as shown in Fig. 4.(b).

We notice here that the new dial depends on the end-stop, the axis, the left, and the right roof. While the end-stop is connected to the axis, the left roof, the right roof, and the quadrant. The two BN structures obtained on BayesiaLab were implemented and expert knowledge was used to set the parameters and complete the conditional probability tables. In this case study, each node has two possible states: functional and non-functional (see Tab. 1). Then, different scenarios were developed to study the inference and propagation of events in both cases (see Tab. 2).

Table 2. Various inference scenarios.

	Original jockey wheel quadrant				Jockey wheel quadrant after desp.			
	Functional	Non_functional	Functional	Non_functional	Functional	Non_functional	Functional	Non_functional
Initial state	69,57	30,43	70	30	98,4	1,6	97,8	2,2
Scenario 1	1	99	0	100	97	3	95	5
Scenario 2	42,9	57,1	43,75	56,25	100	0	96,75	3,25
Scenario 3	31,47	68,53	31,82	68,18	97,64	2,36	95,05	4,95
Scenario 4	0	100	2,4	97,6	97	3	95,05	4,95
Scenario 5	1,98	98,02	0	100	99	1	99	1

As an initial state, we notice that the original obsolete quadrant is functional at 69,57% whereas after despecialization (desp.) it is at 96,03%. Thereafter, there is an increase of 38,03%. This increase proves that there is a considerable improvement and that the new system is more resilient than the old one. In the first scenario, the probability that the quadrant is non-functional knowing that the left roof bearing the stop is non-functional is significant compared to its initial state. It increases from 30,43% to 99%, i.e. an increase of 225,34%. The same is true for the other components, there is a slight increase in the probability of the non-functional state. We can then conclude that the effects of the left roof with the stop propagate to all the other components, which makes its role important in the good functioning of the jockey wheel quadrant. Staying with the first scenario and looking at the results after despecialization, it is noted that the probability of the quadrant being non-functional knowing that the left roof is non-functional has increased from 3,97% to 5,28%; in other words an increase of 33%. For the other components of the quadrant, the effect of the non-functional left roof has no impact. It can be concluded that following the despecialization made on the end-stop by separating it from the left roof, the propagation of the effects of the left roof is much less important on the other components of the quadrant than before the despecialization. For scenarios 2, 3, and 4, the principles remain the same. The functional state of one component is changed to non-functional and the new probabilities of the non-functional state of the other components are noted. If the new values are lower than the old ones, this means that the independence of the components is better assured. In other words, resilience is better. In the case of the new quadrant architecture, it can be seen that before the despecialization of the quadrant, the components are more dependent. The effect of the non-functional state of a component propagates more widely throughout the network and affects the other components. After despecialization, however, this dependency has weakened. The effect of propagation is therefore less important. For scenario 5, we investigated the effect of the end-stop on the other components after despecialization. It was found, as shown in the curve, that the effect of the non-functional state of the end-stop is more important with respect to the quadrant. Its probability increased from 3,97% to 98,02%. On the other hand, on the other components, its effect is very weak or even null. In fact, after despecialization, the force applied on the end-stop will be less important because this force is distributed on the other components. Therefore, the separation of the end-stop from the left roof has made the quadrant more resilient than before. In conclusion, when despecializing the system, the dependency between the components has been reduced. This makes it more resilient and more efficient (cf. despecialization techniques illustrated in Fig. 3). This is the resilient and GBP system curve in Fig. 1.

## 5. Conclusion

Resilience is a key factor that ABMI takes into consideration when despecializing obsolete systems/products. The more

resilient the system/product, the longer its useful life. From the studies we have presented above, we have proven, in one example, that the despecialization of a component has made the system more resilient. The effect of the resilience of the component was propagated among all components and made the system better than before. Demonstrating the resilience of a system after despecialization proves the effectiveness of redesign actions. Therefore, when implementing despecialization for any other system, the main question to be answered is whether and to what extent this redesign guarantees resilience. The authors are currently working on the formalization of a resilience index in order to be able to attribute to any system a level of resilience to obsolescence and shortages. Designers will then be able to (i) choose the best despecialization solution from the set of possible choices based on this index, and (ii) prove to the customer the level of resilience achieved by the redesign.

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