# The Challenge

**Arcadio Reyes-Lecuona**

**Abstract** Industries involved in manufacturing and providing services for high-value, long-life products must address challenges related to upgrading their products once they are in operation. The aim of this chapter is to present some of those challenges, which have been addressed in the Use-it-Wisely (UIW) project using the tools and methods presented in this book. To outline these different challenges and how they are interrelated, an imaginary company is assumed, a European manufacturer producing high-investment equipment for customers worldwide. Their products are complex machinery with a long life cycle, and thus, an important part of the business is focused not only on manufacturing but also on inspection, maintenance, refurbishing, upgrading, and retirement. This chapter presents a brief description of its activities and business areas to highlight the main challenges that this company has to address in the current context of globalization, rapid change and high restrictions, together with other companies and stakeholders that define a value network. Finally, the chapter outlines how these challenges have been organized to discover key elements for addressing them. This organization is a result of the UIW-project.

**Keywords** Product lifecycle · High-investment products · Long-life products · Product upgrades · Product maintenance · Product reutilization · Customer involvement · System modelling · Business modelling · Technological support of collaboration

A. Reyes-Lecuona (✉)
DIANA Research Group, Departmento de Tecnología Electrónica,
ETSI Telecomunicación, Universidad de Málaga, Málaga, Spain
e-mail: areyes@uma.es

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## 1 Introduction

The Use-it-Wisely (UIW) Project gathers several important companies grouped into six industrial clusters, together with universities and other research institutions. They work in vastly different industries with the common goal of investigating new business models and opportunities based on innovative methods of managing continuous upgrades in different industrial product-service systems. These are high-investment, long-service-life, one-of-a-kind or highly customized products such as working machines, ships, trucks, power plant equipment, spacecraft or long-life furniture. These companies are facing important challenges due to global off-shoring, rapid business environment change, shrinking investment budgets, and environmental pressures (Schuh et al. 2011). These challenges can be addressed by creating added value by augmenting their products with agile knowledge-based, environmentally friendly post-manufacturing services. This was outlined in the Factories of the Future roadmap for Horizon 2020 (EFFRA 2013) and other platforms and networks focused on innovation in production, such as Manufuture (2006) or the Intelligent Manufacturing Systems (IMS) project (2011).

During the execution of the UIW-project, the industries involved worked together to describe common interests, visions and approaches to face the aforementioned challenges. Each of them has contributed specific solutions to their problems. Although these problems are specific, there are many commonalities that were captured during the UIW-project. To structure those contributions, we assume an imaginary company in which all these challenges are present. It is important to highlight that the challenges outlined are not the challenges of a single company. A whole network of stakeholders is implied in each of them, whose role is relevant. We have named this imaginary company "Eutopia[1] Ltd." and present these challenges in the next section.

## 2 Presenting the Challenges: A High-Investment Product Manufacturer

Let us imagine Eutopia Ltd., a global manufacturer based in Europe that produces high-investment equipment for customers worldwide. Eutopia is a large company with several thousand employees working in several plants in Europe and provides service to customers throughout the world. Its products are complex machinery with a long life cycle, and thus, an important part of the company business is focused on

[1]The name Eutopia is used as a combination of Europe and Utopia, from ancient Greek: "ou" (non) + "topos" (place), coined by T. More (and used as title of his book, 1516, about an imaginary island enjoying the utmost perfection in legal, social, and political systems). The word eutopia can also be understood from ancient Greek as "eu" (good) + "topos" (place). Eutopia would therefore be a desirable place to be, whether it exists or not.

the inspection, maintenance, refurbishing, upgrading, and retirement of their products as well as their manufacture. Its customers are companies running large facilities, which are subject to strict regulations and operate in a highly competitive environment with rapidly changing conditions. Moreover, many other companies provide products and services to Eutopia's customers, and collaboration and information sharing among them is necessary.

To be able to adapt to the high diversity and rapid changes in market conditions, Eutopia must tackle various problems in the entire product life cycle that involve different stakeholders and other associated companies that define a value network. The next paragraph summarizes these challenges.

## 2.1 Challenge 1: Involving Customers in Early Stages

Due to the high diversity of customer needs and the need to adapt to different environments, interaction with customers for ordering new units must be very flexible and allow a high level of customization. Moreover, some of the products produced by Eutopia are one-of-a-kind products specifically designed for one customer. Therefore, the company needs methods and tools for gathering high-level requirements from the final customers and enhancing the communication among all relevant stakeholders involved in the value generation process, including customers and other service companies.

Therefore, they must develop applications to enhance communication between stakeholders including customers because the first interaction is with them when a product is ordered. The basis of this system should be a product model that is built following a reference data model (meta-model) to store and interchange information about the product design, configurations, data for calculations and simulations. With this approach, the system could provide support for the initial choices among different design and configuration possibilities and associated prices. In Chapter "Space Systems Development", a similar challenge in the space industry, maintaining communication with the customer from the early stages in commercial space service development, is addressed.

This approach is so generic that this improvement in product modelling can serve as a standard for storing and interchanging any industrial information in multiple types of industries, e.g., large series, small series, or one-of-a-kind products (Eigner et al. 2014). Furthermore, Chapter "Extending the system model" describes extending the models to support different project activities throughout the product life cycle and maintaining control of system consistency.

## 2.2 Challenge 2: Factory Upgrading

A rapidly changing market leads to the necessity of continuously adapting and developing production systems (Lindskog et al. 2013). Therefore, factory upgrading as a mechanism to adapt to customer needs is another challenge Eutopia must address. However, modifying a manufacturing system requires complex plans and necessarily involves contributions from actors across the entire organization and beyond (Lindskog et al. 2016). All of the involved actors must collaborate and share a common understanding of the design, functions and performance of the current and future manufacturing systems.

One tool for supporting engineers in preventing mistakes and misunderstandings when working in redesigning an existing factory is virtual representation of products and manufacturing systems (Becker et al. 2005). Therefore, Eutopia is interested in developing applications to store technical information for the production system (3D models of the factory, live production data, etc.) and improving current work activities with a collaborative focus. Its goal is to improve the communication between actors from different departments to make technical decisions including positioning, allocation of work, maintenance, and planning of production-related activities using this information. Chapter "Virtual Reality and 3D Imaging to Support Collaborative Decision Making for Adaptation of Long-Life Assets" contains a more detailed elaboration of the use of virtual representations to improve understanding of existing systems and for facilitating collaboration and decision making in this context.

A particular challenge for a global manufacturer such as Eutopia is to harmonize and standardize the production processes within operations in multiple locations and markets to ensure best practices and the most efficient way of working. Hence, with virtual representations of their production sites, together with a rich collection of associated metadata, the upgrading process can be easily shared among different factories. This allows considering their multiple experiences to improve the collaborative decision making process that is required in modifying a manufacturing system. Chapter "Adaptation of High-Variant Automotive Production System Using a Collaborative Approach" presents an industrial case in a truck factory that addresses a similar challenge.

## 2.3 Challenge 3: Maintenance Management

Once the equipment is sold and in operation, periodic maintenance management is an important business area. Maintenance operations can be undertaken by Eutopia itself or through other service companies that are part of its network. Again, collaboration among the actors involved, which could include the customer, inspection companies, the manufacturer and other maintenance companies for repair or refurbishing depending on the inspection results, is a key challenge of paramount importance (Reyes-Lecuona et al. 2014).

In the case of inspections, the results for each unit sold that is in operation should be stored in Eutopia's information systems and linked to a product realization model built based on the aforementioned meta-model. There, all of the information relevant to the system context is identified and structured. In addition, it is necessary to develop collaborative applications to share and manage this information. Here, it is convenient to link all this information to the 3D geometry of the product.

This challenge has additional implications. In many cases, the product consists of a physical assembly of parts defining the product geometry. This assembly is usually hierarchical, with several levels of sub-assemblies. Maintenance work is usually focused on one sub-assembly or a specific part, and different maintenance services may be conducted different parts of the product or over an area or volume defined within the product geometry. Providing a user-centred design of the 3D interaction mechanisms is essential for a collaborative decision making tool (González-Toledo et al. 2015).

Chapter "Collaborative Management of Inspection Results in Power Plant Turbines" presents an industrial case in which a company working on inspections of power plant turbines addresses a similar challenge and a collaborative tool that has been developed to improve the decision-making process among the actors involved.

## *2.4 Challenge 4: In-Operation Upgrades Demanded by Customers*

Once Eutopia's products are in operation, customers might require different upgrades to the equipment during its operating life, sometimes after a long operation time with possible unknown modifications. This is another challenge as well as a business opportunity. The challenge is to create modular upgrade solutions so that the same parts can be reused in many product models. The company must develop pre-engineered modules for these upgrades so it will be able to provide a machine upgrade service as a new business model [see Leino (2015) for a similar case description].

However, delivery of upgrade modules for physical assets in operation for a long time is not an easy task. It is necessary to build tools and methods to evaluate compatibility between upgrades and machines, prior to design, customization and delivery of upgrade offerings to customers. As the machine has possibly undergone modifications affecting its geometry after a long time in operation, it is necessary to track these changes to ensure that an upgrade module is compatible with a specific machine. This is not easy, as these products might not be under the producer's control after the sales process. In general, as in previous challenges, improvement of communication between actors is essential to interchange commercial and technical information as well as recording the actual state of each unit sold, including possible geometric changes.

Chapter "Rock Crusher Upgrade Business from a PLM Perspective" presents a similar industrial case in which novel digital technology is used to enable a new business model for upgrading old machines in the mining and construction industry. There, the innovative business model is based on clever engineering design solutions of the upgrade products and on digitalization of information flows for upgrade projects.

## 2.5 Challenge 5: Upgrades Driven by Changes in Regulations

There are many more reasons for upgrading equipment that is already in operation. Eutopia's products are subjected to strict regulations. Changes in these regulations, operational data, post-delivery inspections and surveys may lead to a decision that upgrading is necessary. In these cases, the actors involved in this process should have access to an information-rich technical metafile that includes all aspects of the product, including initial customer specifications, designs, trial data, inspection results, and required regulations that may change over time, necessitating an upgrade to extend the operating life of the product (Frangakis et al. 2014). Here, communication among different actors, including regulatory bodies, is essential.

Therefore, the upgrading process requires the company to develop tools and methods to improve the information flow and communication between actors and to exchange technical and legal information. The products should be transformed into meta-products that are accompanied by an information-rich environment.

Chapter "Supporting the Small-to-Medium Vessel Industry" presents an industrial case focused on the manufacture of small craft passenger vessels made of composite materials, which poses a similar challenge. This challenge is addressed by developing a set of tools that enables the storage of information on all aspects of a vessel's life cycle.

## 2.6 Challenge 6: Business Modelling Simulation and Innovation

Current rapid market changes force Eutopia to constantly generate new business models or adapt current business models to innovative ideas. To address these challenges, the company works on innovation management such as business model innovation using system dynamics simulation modelling (Groesser and Jovy 2016; Martinez-Moyano and Richardson 2013; Sterman 2000). Their objective is to produce estimations of costs and updates, thus following market dynamics in the context of increasing the duration of the life of the equipment in service. Such business model analyses allow the company to evaluate the effectiveness of various policy options under varying circumstances and to improve management decision-making.

In addition, such business model analyses could be extended with quantitative simulation models for estimation in the context of business model innovation (Rahmandad and Sterman 2012; Groesser and Jovy 2016). Simulating business cases in a systematic and reliable manner would allow for informed decisions to be made on which upgrades should be conducted.

Chapter "Complexity Management and System Dynamics Thinking" presents how to address this challenge using causal context models and how to extend them with quantitative models for performing estimations.

## 2.7 Challenge 7: Retirement and reutilization

Retirement of old equipment and reutilization of old components in new products is another challenge for Eutopia to achieve flexibility, adaptability, and modularity in its product designs as well as a high level of material reuse and hence sustainability. To achieve high levels of returned material, a new business model should be developed through new product-service strategies based on the Circular Economy (CE) paradigm (Tukker 2015; Lieder and Rashid 2016). In addition, Eutopia must respond to constant market developments and adjust their products, services, processes and business model while accounting for the required sustainability and flexibility of products. In this context, one question is how to retain the highest value of its investments.

To address this challenge, Eutopia has developed a causal context model (Groesser 2012) in which different variables and their relationships are identified (see Chapter "Complexity Management and System Dynamics Thinking"). The causal context model builds the foundation for a simulation-based business model analysis that can be used to simulate the effects of important business model decisions. This is done using a business simulator based on system dynamics modelling to reflect its product and service portfolio using CE scenarios.

Further, the company's approach is to develop a CE Check to support a modular, adaptable product design, creating the possibility of adapting (by upgrading, retrofitting or remanufacturing) the product while in use at the customer site, to prolong the lifespan of the product and meet changing final customer needs. A special focus is on modularity aspects that support the re-use of parts within and between product lines.

Chapter "Sustainable Furniture that Grows with End-Users" presents an industrial case in which this challenge is addressed in the context of sustainable furniture production.

## 3 Addressing the Challenges

The challenges we have presented as those faced by Eutopia Ltd. can be structured in a generic model around the upgrade initiation process. To manage and address these challenges, we can differentiate them into three domains: (1) innovation management and business models, (2) collaboration and data visualization, and (3) Actor-Product-Service modelling. Figure 1 shows the three domains related to the upgrade initiation process.

Market and data analysis using business forecasting models and tools can, from a strategic decision, initiate the upgrade of its product/service or business model. This decision can be supported by business simulation, made by management directly or be the result of a collaborative process to analyse simulation outputs. As an example, a simulator application could be used to study new product-service strategies based on the CE model or to allow the customer to be informed of the costs involved in different possible upgrades. In both cases, the outputs of these simulators will be the base upon which to choose what upgrades should be initiated.

The decision to initiate an upgrade could also arise from technical analysis of the situation. Collaboration management via models and applications that support this collaboration and the knowledge of product status through enhanced visualization can also drive an upgrade decision. As an example, a collaborative application that includes discussion management could help technicians to determine when initiation of an upgrade is necessary.

Both sources for an upgrade decision, based on strategic market estimation or the result of collaborative technical work, should rely on effective Actor-Product-Service models and tools to support decision making. These three domains are described in more detail below:

- **Actor-Product-Service Modelling domain**. Company applications must handle large amounts of information from different sources (3D scan data, CAD models, ad hoc process databases, etc.) A reference meta-model would provide a set of rules to develop specific Actor-Product-Service Models. This meta-model would contain recommendations on how to model information on product and services so that interfaces between different formats and tools are easier to maintain. Information about customers and other actors in the value network can also be included. This meta-model is general enough to serve as a standard for storing and interchanging any industrial information in multiple types of industries.
- **Collaboration and Data Visualization domain**. As noted in the previous section, a recurrent challenge is to improve the communication between different actors involved in the life cycle of products or services. To that end, several methods and tools might be implemented inside the collaboration management domain. These tools would be focused on enabling information flow, promoting collaborations in technical developments, and providing an easy and efficient method for making decisions. As mentioned before, the Actor-Product-Service model organizes all of the information related to the

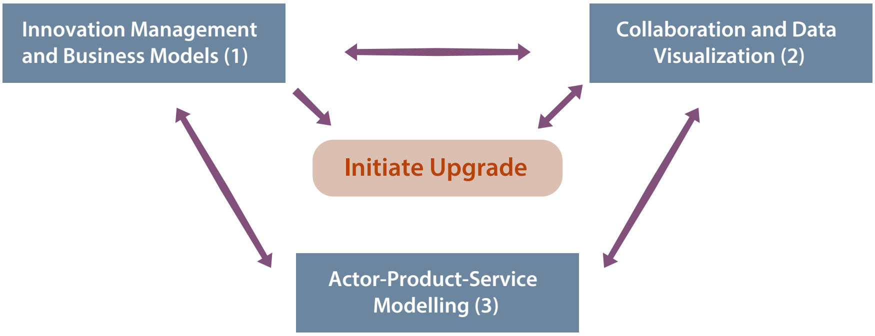


**Fig. 1** The three UIW challenge domains and their relationship with the upgrade initiation process

product/service. This information can be used by the applications contained in this domain to offer: a collaborative environment (in which many actors can interchange technical, legal and commercial information), decision making support (providing a discussion management mechanism) and visualization of the product/service (using 3D models and specific diagrams). The collaboration management domain has two roles. First, this domain can work as the upgrade originator. In this case, actors use the collaboration management tools to study the problem and decide if it is worth initiating the upgrade or not. Second, this domain appears when an upgrade has been initiated and different actors must make technical decisions regarding modifications to the system of interest.

- **Innovation Management and Business Modelling (market and data analysis) domain**. Some of the aforementioned challenges require producing applications and models to perform predictions in the context of business innovation in a systematic and reliable manner to subsequently make decisions about which upgrades should be carried out. To model applications related with the market and data analysis, some generic structures must be defined (Lane and Smart 1996; Lane 1998; Paich 1985; Ulli-Beer et al. 2010). Some of these generic structures, which are basic structures of System Dynamics models, were created during the UIW-project. First, generic business model structures include major business elements with generic values. Then, using an inductive process, other generic structures can be extracted from causal context models. These generic structures should illustrate a basic understanding of upgrading and its effects for the company as well as for the users of upgradable assets. Generic structures are the first element of any System Dynamics model and allow practitioners to model their own upgrading challenges using the generic structures as a stepping stone for a more specific model applied to their challenge (Groesser and Jovy 2016).

## 4 Conclusion

This chapter introduced the main challenges that companies involved in producing, maintaining, and operating high-investment, long-life products must address due to global off-shoring, rapid business environment change, shrinking investment budgets, and environmental pressures. It is the result of an analysis conducted with the industrial partners of the UIW-project and has been presented as the unified story of an imaginary company, Eutopia Ltd. The idea behind this chapter is to present the challenges that have been addressed during this project in developing and testing new tools, methods and business models that build the remaining elements of the book. Companies with similar needs to those presented here as Eutopia's challenges could discover that the tools and methodologies presented in the remainder of this book are applicable to their business.

To address these challenges, actors should be involved in a collaborative process for producing upgrade innovations. In the next chapter, a generic framework for managing these system upgrades is formulated. This framework goes beyond the three-domain model outlined here and is designed to address the challenges presented in this chapter using an adaptation mechanism to manage factors influencing the upgrade design, a system model definition that integrates actor, product and service data, and a virtual collaboration environment to facilitate the interaction between actors.

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