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"DESIGN FOR UPGRADING" OF MACHINES AND PRODUCTION PROCESSES: A GUIDLINE BASED ON ACTUAL DEMANDS OF INDUSTRY AND SUSTAINABLE DESIGN

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Abstract

This paper is about the topic to plan the prolongation of the lifetime of capital goods through a special focus to upgrading during product development and product life span. It is the goal that products are utilized longer and to reduce the essential disadvantages upon the environment. The costs of development and manufacturing for the implementation of the new functions and modules in the product in a later utilization phase have to be decreased effectively.

The discussed guideline "design for upgrading" shows a methodology how to develop products which can be upgradeable in their life span. The three interrelated processes (product life cycle, module life cycle and upgrading process) and the use of resources will be presented, too.

The paper describes the results of two research projects with different companies (bottle filling and labeling machines, train brake systems, high speed printers, etc.) during their product development.

Keywords: Design for upgrading, life cycle, total life cost, sustainable product system, sustainability

1 Introduction

Saving the environment and resources becomes more and more important in the society. This can be achieved in different ways, e.g. recycling, refurbishing and modernization of products [2, 6] (figure 1).

Refurbishing is the repair of the product for reuse at the same technical level during the usage phase. Modernisation is user-individual at the end of the first usage phase. In this case the user will get a greater benefit with expanded functions for a further use on a higher level.

Another way to prolong the usage phase is to "design products for upgrading", which is based on modernisation [5, 6, 7]. When a product is designed for upgrading it will be easier to expand its functions during the usage phase: The product has a special design, so that on the one hand old parts and modules can be replaced by new ones much easier. One the other hand it will be much easier to install new additional functions and modules, too.

To achieve this target it is necessary to develop upgradeable products in a special way. Especially during the process "design for upgrading" all people involved in a upgrading project have to look far into the future. They have to analyse and consider a lot of requirements to the product. Of course, these future requirements are changing during the lifetime of the product

and they will have a great influence on the total product design: modular design, intersections between parts and modules, basic functions, materials …

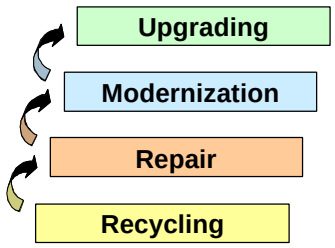

Figure 1. Methods to save environment and resources.

The decisions how to design a upgradeable product have to be made at the beginning of the product development process (“begin-of-pipe”). But not only engineers can decide how to design the product and which functions the product or machine has to fulfill: There are a lot of triggers, which can have enormous influences to the upgrading project and an upgradeable product. The designer can bring all these requirements into a new product design so that this will help to make products much more enviromental-friendly.

When products have a much longer usage phase, which can be achieved by “design for upgrading”, it would be able to reduce the exploitation of material and energy in the production phase as well as in the usage phase. This methodology has financial advantages for the customer and the user, too: The manufacturer could increase the enterprise profit and value. The user can upgrade his product for a perceptible benefit like an increase in quality or process speed, additional features etc.

During product development, an early stage of the product life span, the designer has great influence possibilities onto later product properties e.g. on spare of resources, product life, upgrade capability and cost generation [3, 12]. This is the stage where the use of the methodology has to be started.

“Design for upgrading” is a new requirement to engineers and production companies. They want an easy methodology to understand and selected resources to use, which are less time-consuming.

In this paper the methodology “design for upgrading” will be analysed in detail and described. Also one example of industry will be shown.

2 Objectives

The author will discuss the guideline “design for upgrading”, its methodology, the three interrelated processes (product life cycle, module life cycle and upgrading process), and the use of resources (e.g. design rules, table to estimate life cycle costs, hints to formulate contracts between machine designer, machine user and the customer of products made of the machine).

The paper will show the methodology existing of 14 stages with examples for upgradeable machines. The methodology is the result of two research projects of the Technische Universität München, Institute for Product Development, realized in connection with five companies. The companies, their products and their product development processes have been analysed.

The author wants to support industry and customers to enlarge the product life span. Therefore the two fundamental goals are pursued:

- To reach an enlargement the connections of processes, actuating variables, flows of information and cost/benefit relation of manufacturer and user will be shown. Enterprises have to be able to decide in a very early stage of the product development process if an upgradeable product design is reasonable. In the case of a positive decision a strategic reorientation in the enterprise must take place. The procedure for the preparation of the strategic decision is explained.
- Also the process of “design for upgrading” will be described. The differences between “normal” product development process and “design process for upgrading” will be shown.

Also some hints to other methods and resources will be given (e.g. target costing, change management, documentation of design process).

The methodology is useful for designing production machines, capital goods and their components. It is not developed for buildings, chemistry and industrial plants, cars as well as household products.

3 Processes of an upgrading project

In every design process the designer takes care for the requirements of the market and the customer. A normal product life cycle will end after the utilization phase I (figure 2).

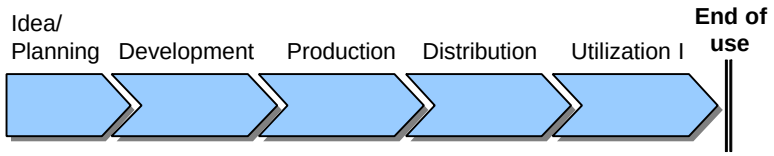

Figure 2. Life cycle of a common product.

An upgrading with new functions or modules can or has to be made after first utilization phase I of the product or machine. The same user still wants his familiar product but with new and considerable advantages (e.g. cost- and energy-saving features or he wants to produce other products with the same machine). In this case the product will not be sold or recycled, but could be used much longer.

Figure 3 shows the product life cycle with upgrading. It becomes obvious that the systematically “thinking” and planning plays an especially important role if the processes are more specified and it is kept in mind that the sense and purpose of upgrading is to enable further utilization phases. Without a specific procedure in the early stages of the product design an upgrading in the sense of the definition is not possible.

Figure 3 also shows the three processes of upgrading under the shelter of trends, environment as well as possible visions. On the one hand the participants of the project (designer, customer, company management, participants in the market …) have to look far into the future and ask many questions for this purpose. On the other hand the information about future processes, conditions and trends have to be evaluated to increase the knowledge. This knowledge must be preserved and flow into further project. A very detailed representation of the processes is possible through an intense analysis of the processes and further specification of the process phases.

3.1 Product life cycle

With upgrading a product is planned first and its form is finally defined at the end of the development phase. The decision to design a product that meets upgrading needs an extensive analysis and planning of several factors, like the users, laws, costs, etc., with a special focus on the additional use phases. These influences must be determined, analysed and evaluated. Their possible characteristics and effects must be described and must be included into further planning and decision steps. Therefore the know-how and the competence of several departments of the enterprise like distribution, marketing, investigation must be joined with external expertise to get verified information for the strategic plans.

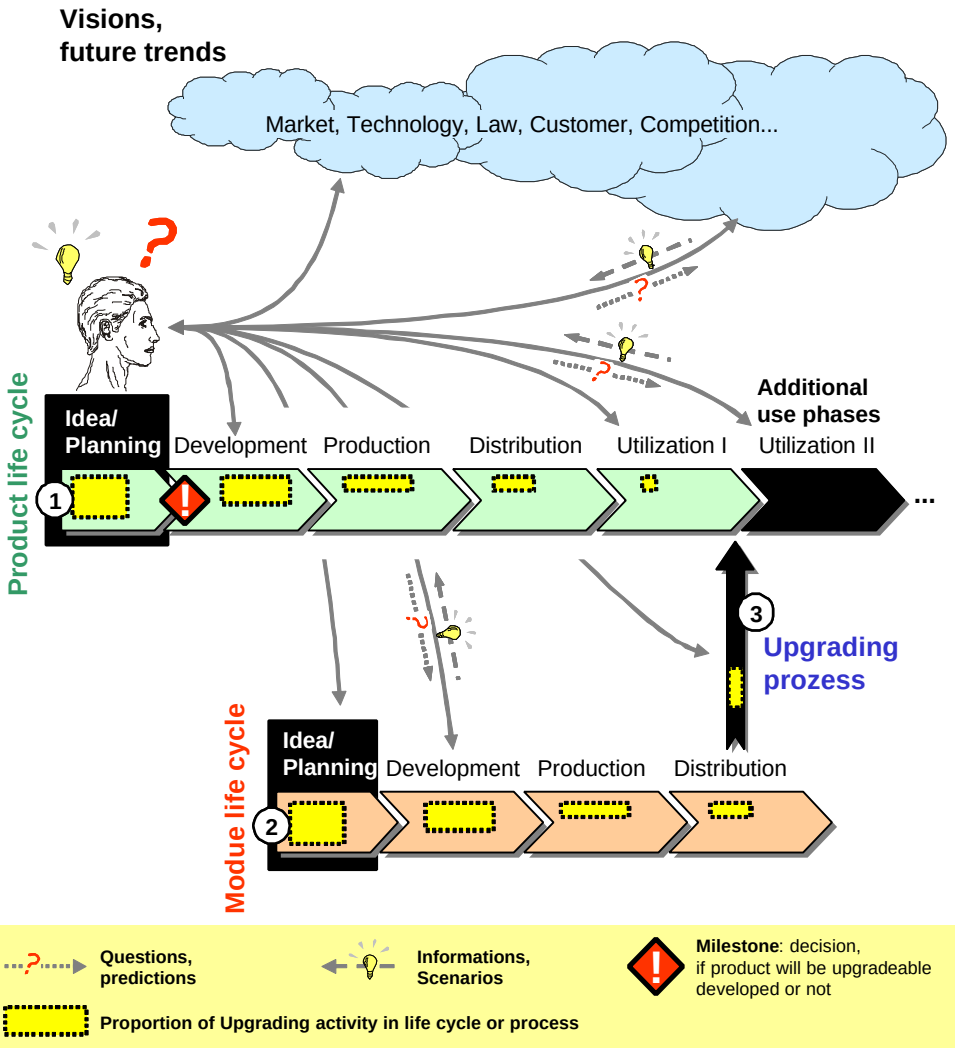

Figure 3. Schematically represented life cycle of an upgradeable product with accentuation of the question formulations necessary in the early return flow of phase and the return flow of information [5].

Information of later product phases like the manufacturing, assembly, distribution, utilization I or recycling must be considered as requirements to the product in the planning and development phase. Many information and experiences flow due to the intense forecast and planning from the later phases to the earlier ones. Early and precise information enable to make more rapid and precise forecasts and management decisions.

During the project the decision has to be made whether the product should be upgradeable - to use it in a later utilization phase II - and further upgrading processes should be completed due

to plans, forecast and cost estimations. A late decision allows to widen the information and knowledge base which the decision will be based on. On the other hand later changes and corrections are extensive and cause high costs since they increase with the product course of life steeply [1]. Accordingly a decision must be made maximally early, nevertheless the forecasting and the further procedure must be checked severely and be compared continuously with the project status.

The first coarse question and activities of the module life cycle have to be done parallel and in conjunction to this activities till the first milestone.

3.2 Module life cycle

To bring more function into the product and benefit to the customer at the end of the utilization phase I some parts or modules of the product must be exchanged or additional parts or modules must be installed in the product. They are defined as “upgrading units”. The actual detailed development of the upgrading unit starts some time after the delivery of the product. The unit should be available at the end of the first use phase.

The module life cycle contains the entire life cycle of the upgrading unit and upgrading functions from the finding of an idea till to the delivery to the customer, perhaps also a later taking back and the recycling.

A decision whether the upgrading project is continued must be made to a specific date. This decision must be supported through information from and about the module life cycle. Thus early phases of the module life cycle have to run parallel to the early phases of the product life cycle. Already some coarse data must have been determined.

The gained information flow back in the early phases of the product life cycle and cover the decision. With the highest priority ideas for the function expansion have to be determine, the module life cycle and the upgrading unit have to be planned as well as the first conceptual activities. Also a decision in order to determine which technology and/or which concept will be detailed and become integrated into the product must be made.

3.3 Upgrading process

New or changed product units, which are planned, developed and manufactured in the process of the module life cycle, have to be implemented into the product or have to exchange old product units to achieve a second utilisation phase with changed and adapted functions.

Therefore the upgrading and/or conversion process is needed. Also this process has to be roughly planned already in the early phases of the product life cycle. The analysed information flow back into the early phases of the product life cycle.

Furthermore the requirements of the upgrading process have to be considered in the module life cycle and for the unit (weight, transportation, volume, etc.), because the upgrading process determines in detail, when and who is doing the conversions or modifications of the product.

The sense and purpose of this process is to give additional benefit to the customer: The customer receives an additional property and function or consisting product qualities / functions are extended in their quality. It allows a varied utilization phase and is supposed to provide an economical advantage to the customer at the same time.

4 Guideline “design for upgrading”

Different reasons are known why to start a project of product development. Much more reasons are known or have to be known why to start an upgrading project. Especially the triggers which appear during the usage phase become very important to an upgrading project (figure 4).

In the first stage of an upgrading project these triggers have to be analysed (figure 5, stage 1). The company has to know why it wants or has to develop and sell a new product and under which circumstances (law, politics, market, competition …). That’s the reason why all connected ressorts (marketing, service, distribution …) in a company have to work very close.

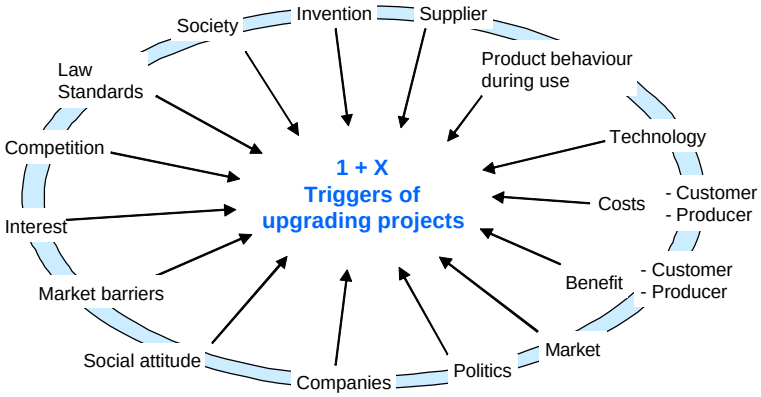

Figure 4. Triggers of an upgrading project [5].

All the following stages (questions, analysis, decisions …) of an upgrading project are combined in a check list or guideline (figure 5). The stages in figure 5 are arranged sequentially but, of course, it is also important to work simultaneous as shown in figure 3.

The main attention is given on the early phase of the project up to the stage “strategic decision”. In this list the operation steps are represented more detailed whereas the further procedure for the module life cycle and the upgrading process is abridged. Each step can be supported by selected methods and aids.

The step “To determine the strategy” is considered to be the milestone with the highest priority at the end of the early phase. At this time the product manager should be able to make a decision for or against an upgradeable product. The decision is based on “relatively” secure information and data during the early stages of a product development process. In spite of that it is necessary to adjust the further procedure with the set goals again and again and to initiate corrections in the case of deviations according to priority. This would lead for example due to new trends, trend corrections or technologies with fatal differences to a further (partial) cycling of the step “To analyse project triggers” or in the worst case to a late breaking off of the project. Alternatives are also possible:

- Continuation with the goal of the evolution of an upgradeable product,
- termination of the project,
- continuation in “conventional” manner, that is without the goal of a upgradeable product.

With the representations it should not be impossible that several module life cycles and upgrading processes encounter a product life cycle. This would extend only the product service life in the sense of this model.

The shown model is not supposed to make the conventional product creation process more complicated and extended. Therefore product manager and developer are involved in too many projects and burdened with in part extensive methods [9]. Nevertheless an enterprise should become aware of the required operation steps in order to gain a long-lasting, upgradeable product.

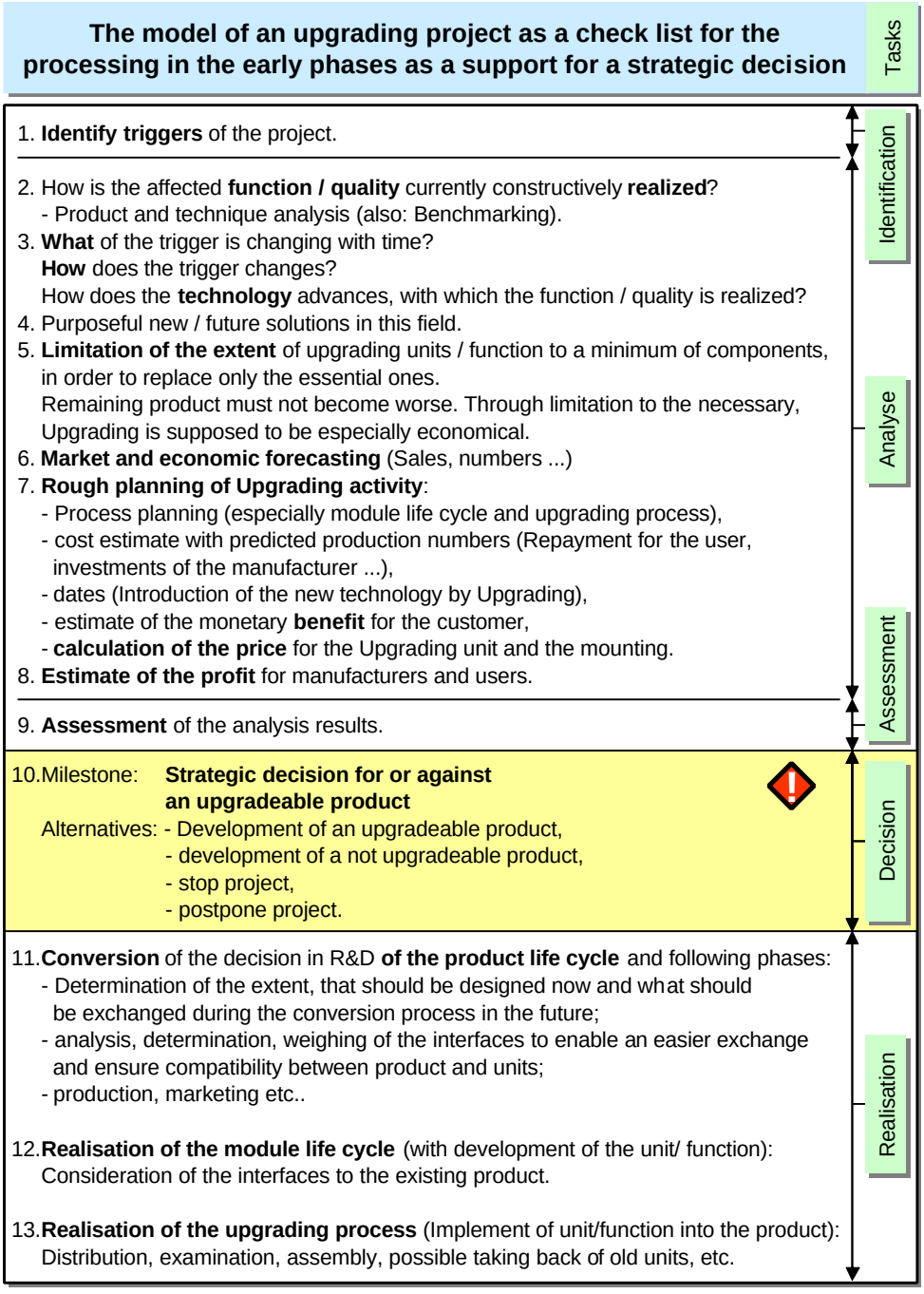

Figure 5. Guideline “design for upgrading” [5].

Additionally to trend research there are a lot of methods and resources for “design to X” available, e.g. change management [1], FEMA, early determination of product properties [10]. They are alredy known [11] and able to support the “design to upgrading”. It is also very important to work with methods of cost estimation and precalculation of costs during the hole product development process [4].

5 Example: Label pasting machine for bottles

Normally bottle filling and labeling machines had an integrated product design (figure 6 left).

Because of an intensiv market research (the so called “look into the future”), e.g. during exhibitions and close connections to customers, it was able to analyse customer requirements: The customer needs machines which can fill different sizes of bottles and paste labels on them. So the producer of the machine (Krones AG) designed a new, modular label pasting machine (figure 6 right). Now the machine is able to use actual lables and bottles as well as other kind of labels which could be used from the customer in future (e.g. for cold and hot pasting, self-sticking). When the size of the bottles or the kind of sticking will be changed the pasting modules can be changed very easy during production and filling of the bottles. The company was able to give different advantages for the new product concept:

- The machine is variable to different lable sizes.
- The module is designed in a special way to repair and refurbish it very easy.
- The customer can use other or future modules as well, so the labeling machine is upgradeable.
- The modules can be changed very fast, so the machine will be in production in a short time, also the time and costs of stopping the production process are very short.

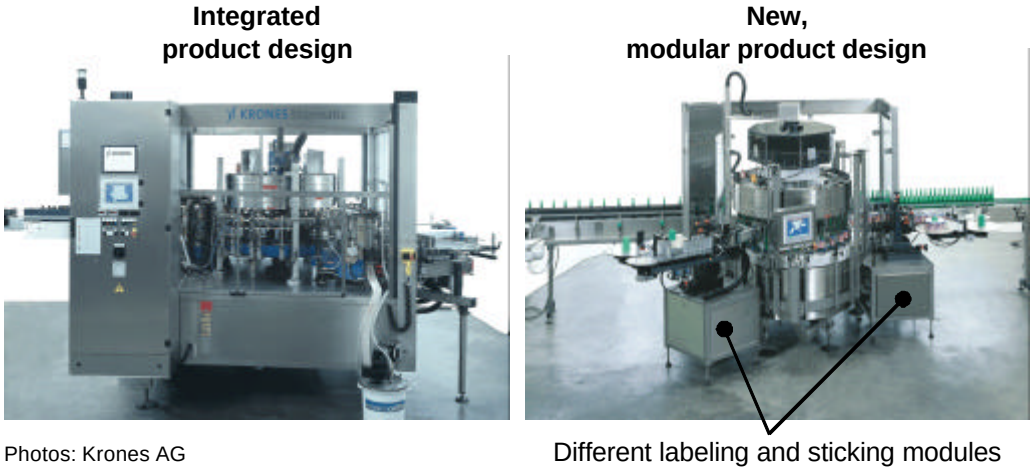

Figure 6. Label sticking machine for bottles: Integrated (left) and new modular product design (right).

The company is also able to give some advantages for the environment and for a longer usage phase of the machine, e.g.:

- The custumer doesn’t have to use all the lifetime the same labeling and sticking concept, he can change it in future because of the modular design.
- The modules can be bought or exchanged sometimes in the future. The electronic parts and connections can work together also in future.
- Different labeling modules can be used at the same time, because they are very small.

To design an upgradeable product or module the company doesn’t only have to use rules like “design for modularization”. It also had to look into the future and find triggers which will change the product design in future. These requirements can be considered in a requirement list.

6 Key conclusions

Increasing output figures and shortened innovation cycles are examples for ascending environmental problems. Consequently, new demands for the integrated product, process and machine development arise. The holistic foresight and analysis of trends allow to use the changing requirements for the design. When simple adaptations are made to a machine, several cycles of use will be possible. A new method and the implementation of specific tools in the early stage of a project is intended to support companies (producers and user of capital goods) in the mentioned “design for upgrading”. The costs of development and manufacturing for the implementation of the new functions and modules in the product in a later utilization phase can be decreased effectively (figure 7).

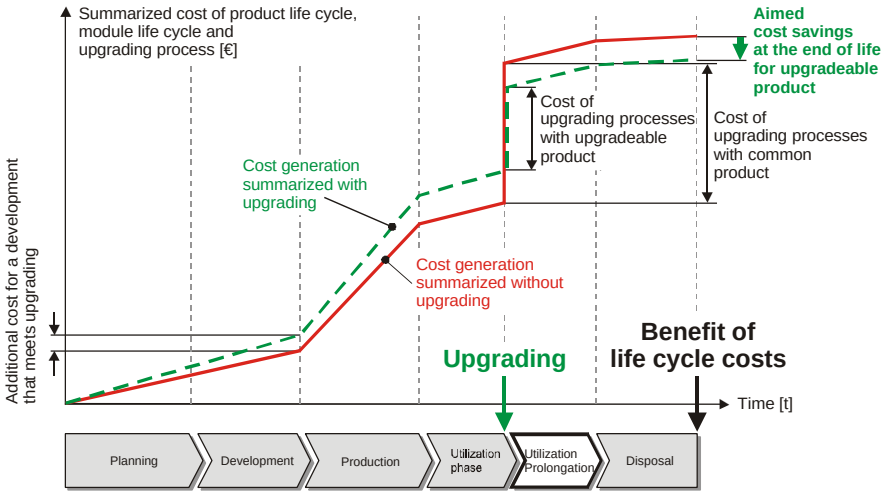

Figure 7. Expected cost savings up to the life cycle end through upgradeable products [5].

Of course, the introduction of methods in a company takes some time and the effort of a project will just appear in a few years. But the more know-how the company collects the easier it will be to make the right decisions. In the end the advantages of “design for upgrading” can be summarised as follows:

- Environment and resources will be saved.
- New business fields can be obtained (benefit: for the producer).
- New technologies and innovations are recognised earlier.
- Product life cycle costs are lowered (benefit: for the customer).
- The time to market of innovations is speeded up.
- Safety of the predictions about future evolutions and trends increases.

The usage of the methodology shows that it really will be helpful in many ways to design and order the right machines and to save money and environment!

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