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THE GUIDELINE "DESIGN FOR UPGRADING" AS A MEDIUM FOR SUSTAINABLE DESIGN

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1. Introduction and goals

1.1 Initial situation

The optimisation of products concerning their environmental effects is becoming increasingly valuable for the society.
On the other hand, survival without technique is possible only for few on a lower level. Engineers alone cannot solve these problems since they have to deal with many restrictions out of the social market, economy, competition arrangement, financial market, teamwork, etc. Following diverse activities in the evolution of recycling technologies the demand for foresighted measures during the product design ("Begin-of-pipe") increases significantly.
The state and society require for new products' more sustainability already in the early phases of the life cycle since product planning and development show the greatest influence possibilities onto later product properties (figure 1).

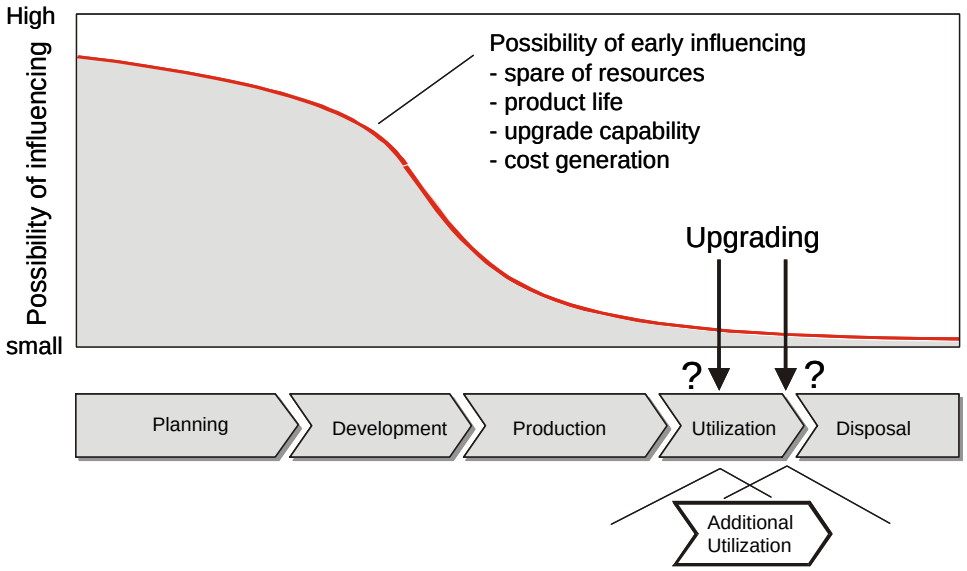

Figure 1. Responsibility of the developer, influence possibilities in early phases

The service life of products can be prolonged in different ways, for example through repair of the product for reuse at the same technical level or through product and user-individual modernisation at

the end of the first utilisation phase, to offer a greater benefit with expanded functions for a further use on a higher level to the customers. To develop the thought of prolonging the utilisation phase any further than the modernisation the approach of upgrading in product development can be found.
In practice upgrading activities are only done if unambiguous advantages can be found under weighing of various factors. An economic stimulus should be available for the ecologically reasonable and voluntary measures to support a longer product use.
For example financial advantages can be:

- for the manufacturer: they have to finance the upgrading activities during product design in advance and in addition they would like increase the enterprise profit and value.
- for the user: they will only upgrade their product for a perceptible benefit like an increase in quality or process speed, additional features etc.

Upgrading is already known in its basic principle as the benefit increase of an existing product during or at the end of the first use cycle. In this paper especially the processes and the procedure during the product planning and development will be analysed in detail and described. It is supposed to prepare strategic decisions that must be made within Upgrading activities.

1.2 Goals

The described initial situation lead to the approach, to reach a prolongation of the service life with new solutions. A possibility of the prolongation and enlargement of use is to design products that meets the aspects of Upgrading. This requires extensive considerations of complex related processes and influence variables. Science and research haven’t had a close look at the topic of prolongation the service life of products through Upgrading and therefore an unsatisfied demand still exist.
In our project two fundamental goals are pursued:

- a support should be given to enterprises through a clear representation of the connections of processes, actuating variables, flows of information and cost/benefit relation of manufacturer and user. They should be capable to analyse, whether the requirement to design products that meets Upgrading 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 with a model.
- subsequently the processes of Upgrading are described. The difference between a "normal" product design and one which meets Upgrading and the following phases are identified.

The expected savings and service life prolongation by benefit and functional complement are supposed to be reached by following points:

- Early planning of mostly the whole entire product life cycle and the utilisation phase, for example including the integration of the customer into product design;
- Preventive planning of the changes of the product properties during his use, for example through wear and corrosion;
- Inclusion and consideration of external factors influencing the use behaviour already during the product planning;
- Realization of a time adjusted Upgrading ("Upgrading depth") and development of components with similar service life to avoid over dimensioning and resource waste;
- Forecast of Upgrading processes in the future and the related activities (i.e. logistics, dismantling, cleaning, arrangement, function test) during the product design.

This approach is restriction to a specific product spectrum. The emphasis of the considered product spectrum is primarily on productions machines and plans, capital goods and their components.
On the other hand following products and plants are excluded explicitly like buildings, power stations, chemistry and industrial plants, household products and machines. In addition it doesn’t deal with the complete dismantling and reconstruction of machines or of railroad freight cars. A possible variant of sustainable products is - maximally long to use the products. Long-living products offer indeed many chances for all participants. It is not to be overlooked however that in sum not only the environmental aspects are decisive for or against their development on the manufacturer side as well as purchase and use on customer side.

1.3 Term of Upgrading and Definition

The benefit increase of an existing product for the product customer is meant by Upgrading. The benefit increase is achieved by a functional completion or functional change during or at the end of the product life cycle. These function expansions were not projected completely during the delivery of the product through the manufacturer, however they were considered during the farsighted product development (due to trend analyses, technology investigation, etc [Figure 2]) in order to simplify a later Upgrading process.

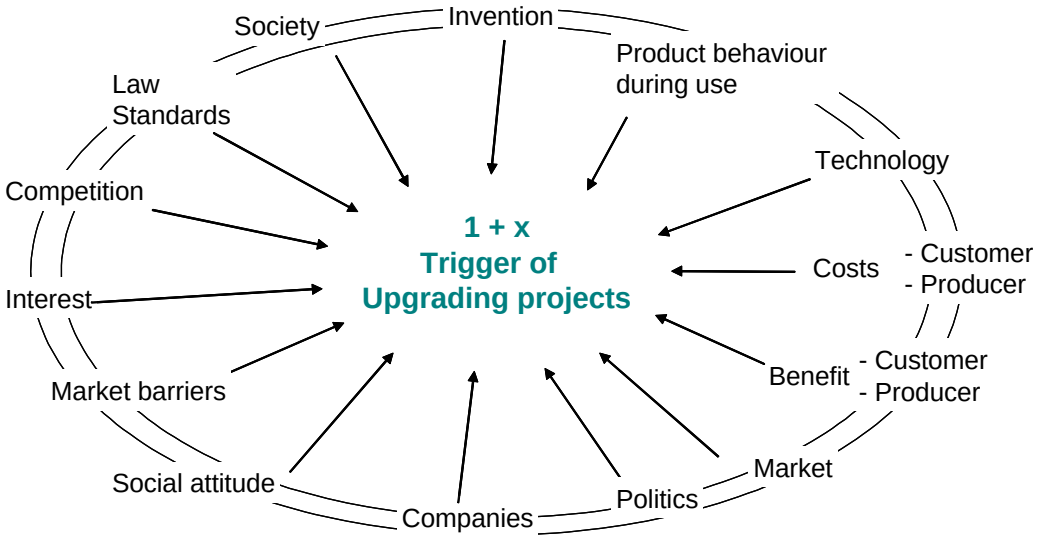

Figure 2. Trigger of an Upgrading project

The product that meets Upgrading is therefore "upwardly compatible" for functions which haven't existed during the design or which haven't been detailed.
Products that are supposed to be upgrade-capable during their use must formed for it and the operation steps during the first product planning, development and design must be aligned to a future Upgrading process (PHLEPS 1999, S. 52ff).

2. Processes of Upgrading - Representation of the field of action

2.1 Presentation of the processes

Figure 3 shows the comparison of the product life cycle with and without 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 utilisation phases. Without a specific procedure in the early stages of the product design Upgrading in the sense of the definition is not possible.
The figure also shows the three processes of Upgrading including the related modifications of the environment as well as possible visions. The participants of the project 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 tendencies have to be evaluated to increase the knowledge. This knowledge must be preserved and should 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.

2.2 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 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.

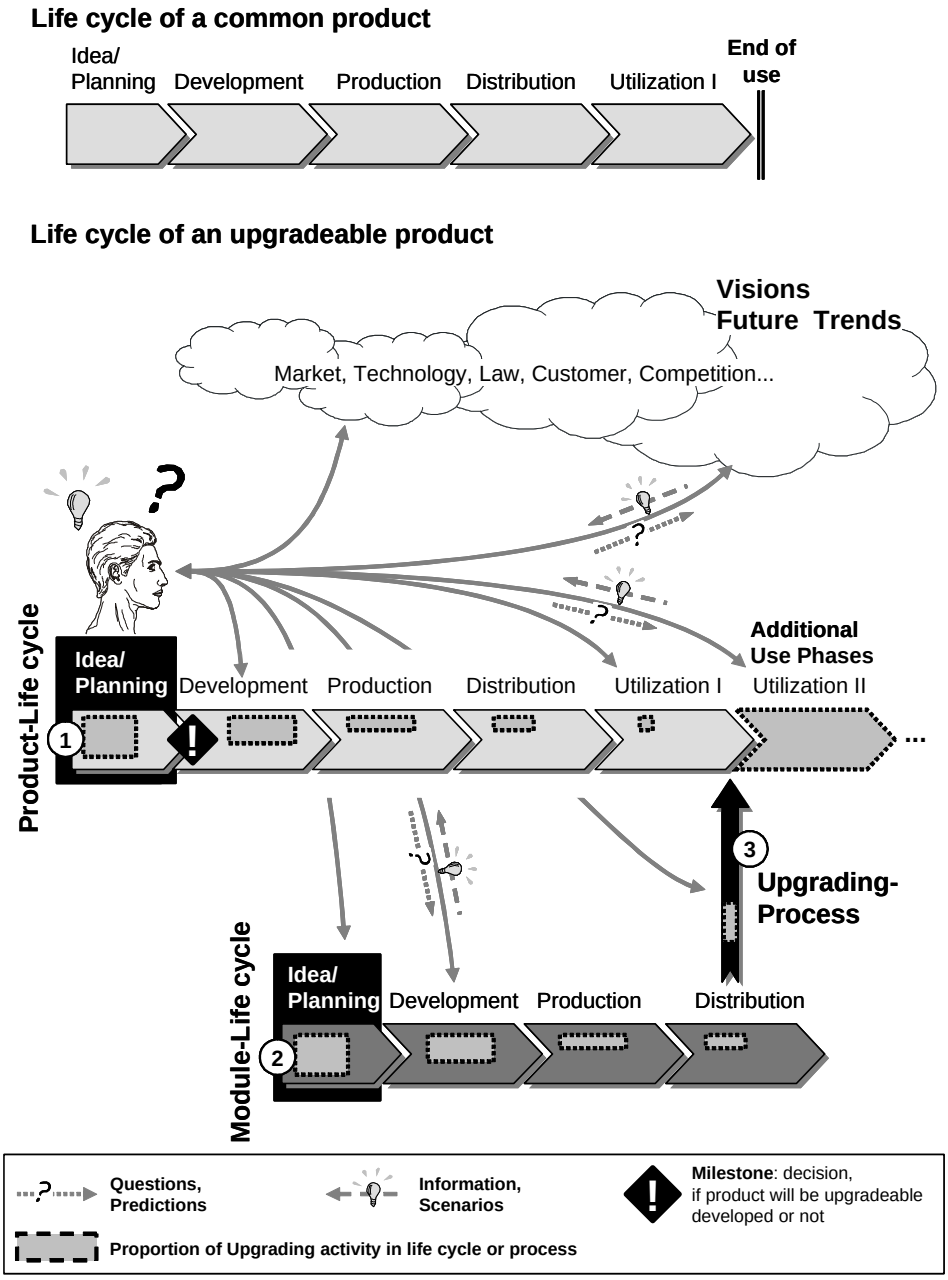

Figure 3. Comparison of schematically represented product life cycle without or with Upgrading with accentuation of the question formulations necessary in the early return flow of phase and the return flow of information

Information of later product phases like the manufacturing, assembly 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 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 (Ehrlenspiel 1995, pp. 561). 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 question and activities of the Module–Life cycle have to be done parallel and in conjunction with this activities till the first milestone is reached.

2.3 Module-Life cycle

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 raw coarse data must be 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.
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 and fit into the original product or be capable to replace units with are not up to date any more.

2.4 Upgrading process / conversion 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 planned roughly in early phases of the product-life cycle. The analysed information flow back into the early phases of the product-life cycle and cover the decision for or against an Upgrading.
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 utilisation phase and is supposed to provide an economical advantage to the customer at the same time.

3. Model of the procedure in a development for upgradeable products

3.1 Introduction

The model of the procedure of an Upgrading project is introduced on the basis of the preceded definitions and the coarse representation of the processes in Upgrading. Maximum attention is given on early phases (Planning of the upgradeable product) in the product life cycle. The product manager should be able to make a strategic decision for or against an upgradeable product already during the first ideas and planning phase with "relatively" secure information and data.
The methodology of the procedure cycle can be utilised in the Upgrading project and in accordance with it a procedure model can be drawn up. The operation steps are here ordered sequentially unlike the representation in figure 3. Here it is clear that the operation steps within a process take place after each other (an engineering Simultaneous is not here represented), the processes of the product-life cycle, module life cycle and the Upgrading process however in part parallel and with chronological overlaps.

3.2 The model

The operation steps of the model are combined as a clear check list for the processing of an Upgrading projects in figure 4.

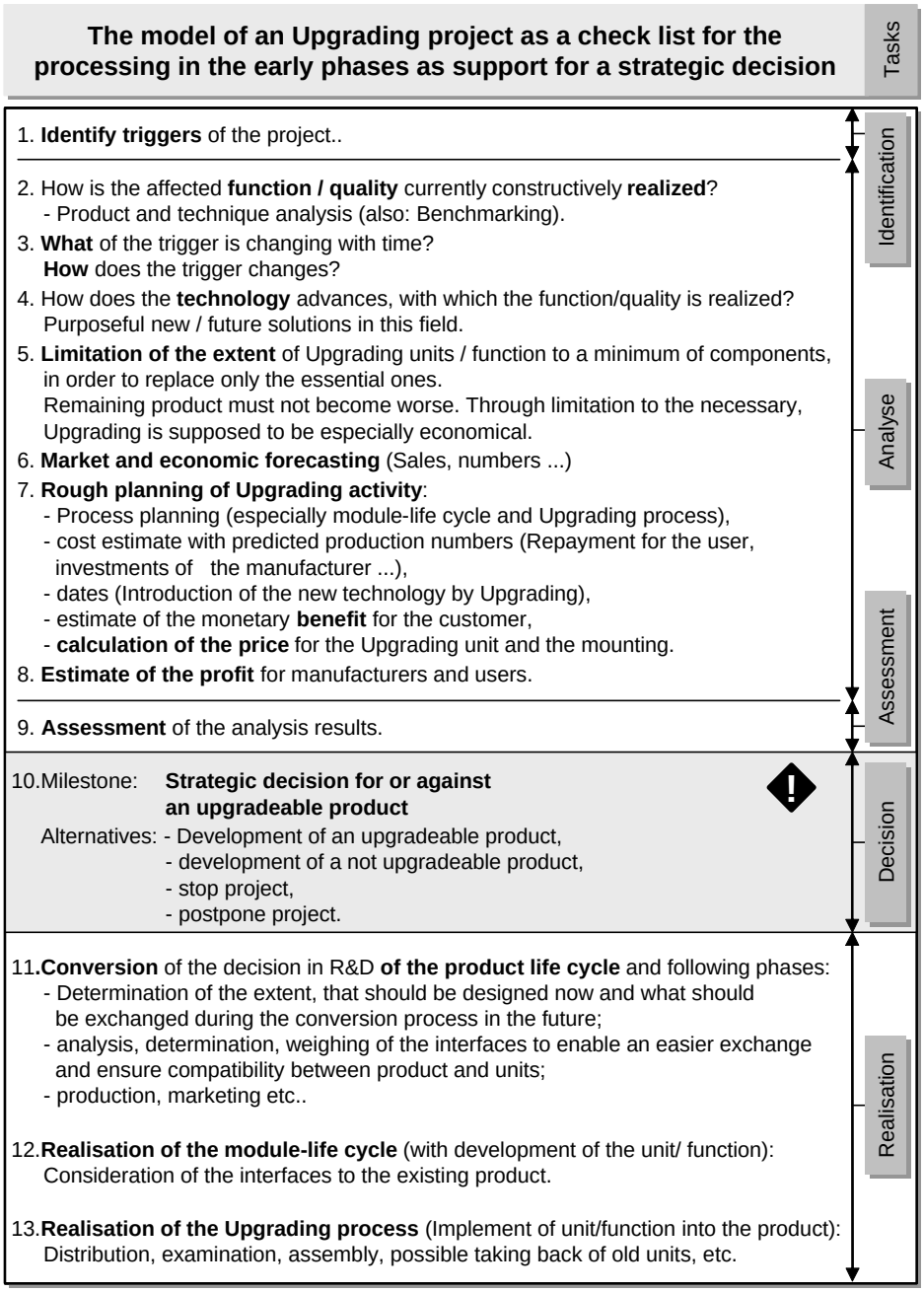

Figure 4. The model of an Upgrading project as a check list for the processing in the early phase

The main attention is given on the early phase of the project up to the 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. In spite of that it is necessary to adjust the further procedure with the set goals 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 is be possible that several module-life cycles and Upgrading processes encounter a product-life cycle. This would extend only to the product service life in the sense of this model.

The model shown is not supposed to make the conventional product creation process more complicated and extended. Therefore product managers and developers are involved in too many projects and burdened with in part extensive methods (Schlueter 1999). Nevertheless an enterprise should become aware of the required operation steps in order to gain a long-lasting, upgradeable product.

4. Summary

In this paper it is shown how a prolongation of the service life can be achieved especially by Upgrading. The processing of an Upgrading of project is supposed to take place by means of a specific procedure and the help of selected methods and aids. With that important information about the entire product life and also about future, changeable use cycles can be received already in the early phases of the product planning and development. These are the bases for the necessary strategic decision whether upgradeable products are reasonable for the enterprise.

The elaborat systematically procedure model is supposed to be applied already in the early phase of the project. Through that the life cycle costs of a product with the Upgrading process should reduced considerably compared to the life cycle costs of a conventional product. Both the producer and the customer can benefit from this economic advantages.

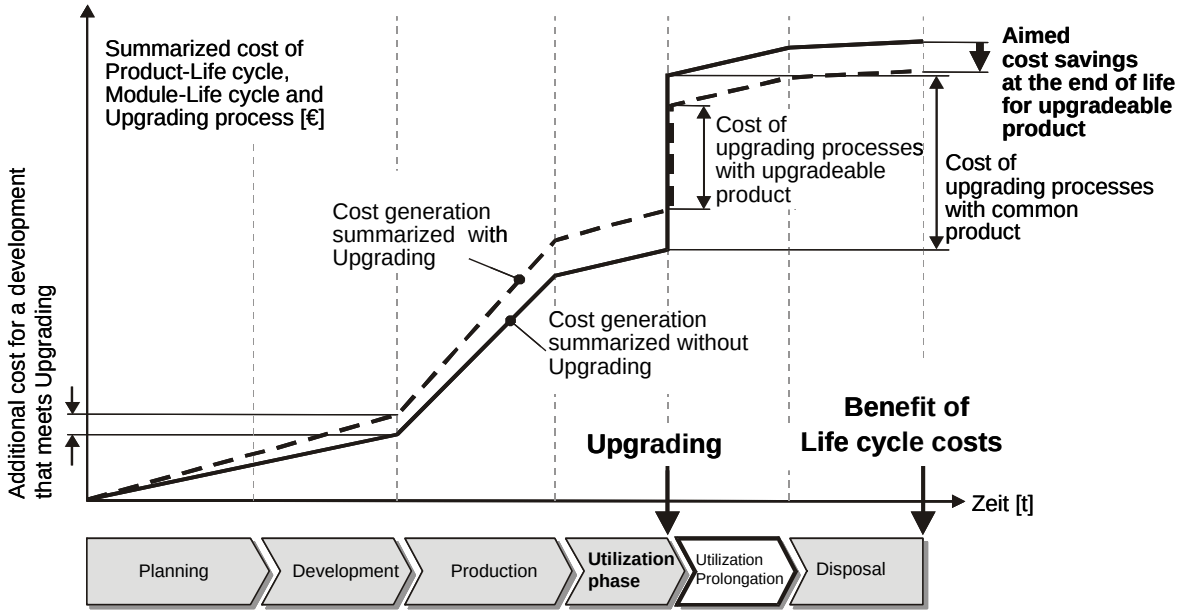

Figure 5. Expected cost savings up to the life cycle end through upgradeable products

Figure 5 shows in conclusion a schematic representation of the costs cumulated through the entire life cycle and the economic advantage targeted in this case through upgradeable product design. This economic advantage - next to the consideration of the further actuating variables (Change of the law situation, of customer requirements, etc.) - should add to the knowledge and willingness for planning and development of long-lasting products, with first priority for an Upgrading.

The possible advantages of an upgradeable product design, if it is carried out with the shown procedure model under application and consideration of methods and aids, 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;

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