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CONCEPT DEVELOPMENT FOR INDUSTRIAL CONTEXT

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ABSTRACT
Industrial companies are faced with a pressure from two sides: First, the evolving life cycle requirements set by the market calls for new product functionalities. This pressure drives the companies to adopt systematic ways of boosting innovation and launching new products. Second, the owners and other stakeholders expect reasonable profits from the company. New innovations and an efficient cost management process are important in a dynamic product market, where an increasing number of companies is adopting global manufacturing strategies. Within the product development context there are three main dimensions that an industrial company must manage: cost, functionality, and performance. These dimensions can be related both to the product and to the development process. In this paper we discuss conceptual design, in general, and development of existing products, in particular. We base our reasoning on the experience gained in real product development projects and on the findings from the Finnish industry. We develop a new understanding for concept development, and encouraged by the discussions conducted in various researcher workshops of C_DFMA Research Program, we propose a new approach to support an incremental innovation process.

Keywords: Product development, conceptual design, industrial products

1 INTRODUCTION
As has been shown lately in the literature, e.g. in [1], [2], and [3], the product concept in various life cycle contexts is a powerful means to support the product development project in such a way that successful products can be launched in the market.

The majority of the development efforts take place with the existing products. What is seen conceptual depends on what differentiates the current products from the competing products in their use context. Hence, a new conceptual aspect may be a product's feature or a specification that carries a new idea to provide benefits either on the market/need or the design/realization aspects.

This leads to an interesting question: how to create a product concept that takes into account the future development needs? This kind of development is related to the product's use context and the requirements for life cycle properties coming from the market.

Today there are a variety of product development methods available, like the ones presented in [4], [5], [6], and [7]. However, selecting the most suitable one requires consideration about the design premise and about the objectives of the project. The development process for the existing products or concepts is different from the processes or methods intended for new products.

In the product development project it is important to see the future requirements in the early phases of design. These requirements may not call for immediate realization, because the users may not be ready to pay for product's features if they consider them redundant at the time of investment, [8]. In contrast, the manufacturer must take these features into account when developing the product concept, which must allow for a series of new or extended concepts (referred to as the incremental concepts) to be developed later. Based on this principle of incremental concept development, a rapid implementation of improved or upgraded products proves to be possible.

This paper deals with the product development process of industrial products and focuses on the incremental concept creation, which allows for an efficient reuse of existing and proven solution elements. The incremental concepts will materialize the product improvements that are considered important in the future, both by the user and by the manufacturer.

2 MOTIVATION AND RESEARCH METHODS

This work is motivated by the experience on conceptual design that we have gained while working in various tasks in design management. The outcome of a typical development project is a product or product family that is planned to meet the customer's needs at the time of introduction. The evolving needs are satisfied by means of product upgrades with enhanced performance and life cycle properties. For the most part these upgrades are based on the original product concept. This approach does not utilize the technological evolution to the full extent. On the other hand, the knowledge needed for developing the enhanced product concepts is fragmented and this fragmentation will become larger with global manufacturing. Our findings from the Finnish industry support this experience.

The work is based on the theories and conceptions of design science. Our approach is conceptual-analytical. We don't strive for new knowledge in particular but for finding a new approach to support the incremental innovation and the conceptual design. The current models and theories are used from different areas, particularly from the theory of technical systems. The view on the problem area is pragmatic and based on our experience in the field of engineering design in the industry. We have presented our findings and discussed them in the researcher workshops as a part of the C_DFMA Research Program in Finland.

Within this work we contrast the concept development tools found in the literature with the processes currently applied by the selected industrial companies in their development efforts of existing products. Along with our experience in the industry we form two views on the subject and propose a new approach for the concept development.

3 BACKGROUND

3.1 Market needs

The evolving market needs call for new functionalities and better life cycle properties, such as usability, operability, and serviceability. Together with the profitability pressure, the external market pressure pushes the companies to search for ways to balance between the costs and the life cycle properties of the products. This, in turn, forces the companies to generate new concepts that are utilized both to improve the existing products and to develop new products. As a consequence, three major constraints must be managed: the cost constraint, the time constraint and the performance constraint.

The new technologies in different disciplines offer opportunities for improving the product's performance. Also new materials enable to develop constructional structures, which are lighter than before or alternatively to increase the product's performance in terms of power output. The developments in electronics and computer software allow for building more advanced control systems, which make it possible to operate the product more cost-effectively.

The product meets various process systems throughout its life cycle, which are shortly called life phase systems, e.g. design, procurement, manufacturing, assembly, test run, distribution, use, service, and disposal. The product's requirements for every system meeting can be expressed in terms of corresponding properties, called here life cycle properties.

3.2 Views on the product concept

Hansen & Andreasen [1], [2] introduce two aspects for a product concept: *idea in* and *idea with*. The requirements for profitability, as presented in Figure 1, create a cost pressure, which is the driving force for reducing costs of the products.

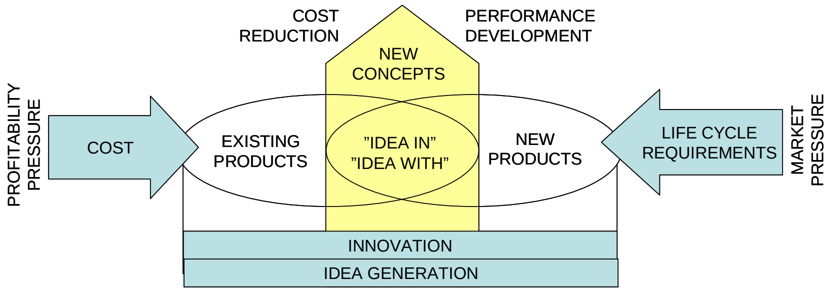

Figure 1: Two views on the product concept in the context of product development [3]

An industrial product can be decomposed into subsystems or chunks. The cost reduction activities are then focused on the selected subsystems. These activities call for new ideas to improve the manufacturability. They can also involve the introduction of optimized specification or new technologies. These goals obviously contribute to the 'ideas in'. On the other hand, the market has increasing expectations on the product's life cycle properties. The development of product's performance calls for new functionalities, which carry new 'ideas with'.

4 FINDINGS FROM THE INDUSTRY

In the following we present the findings from the Finnish industry, which were discussed in a researcher workshop in Tampere University of Technology[1]. These findings show that the conceptual design in an industrial context encompasses several dimensions, which have to be taken into account in the product development projects.

4.1 Delivery process and decision making

At the conceptual phase the company must match the customer view, the designer view and the production view. However, it is rather usual that the customer is not invited to participate in the activities of conceptual design. On the other hand, the companies have problems in maintaining the producibility[2] of their systems when an extended product enters the process.

The companies do not utilize the process thinking to the full extent. This gives rise to the traditional 'over-the-wall' engineering. Sometimes the decision-making is inefficient. Knowledge for a proper decision-making is missing or it is not available at the right time. It also seems that the companies concentrate on too small or even wrong things: the decisions are based on a less-scrutinized problem analysis, which leads to treating the symptoms instead of clarifying and removing their causes.

In many companies the planning is not efficient and easily leads to plans, which are not in line with the original targets. This may create uncertainty about deciding upon the back-up plan. Another aspect of this is the uncertainty about when to reject the back-up concept.

4.2 Timing and risks

In many cases the ramp-up time, or the time to the planned volume, becomes too long. This may be due to the fact that the typical problems of ramp-up are underestimated or they are even unknown. It is also usual that the new product concept does not fit the current delivery process. Often this manifests itself in problems in managing the inbound logistics.

In striving to shorten the time-to-market the companies are setting too tight schedules, which do not allow for charting alternatives properly. This brings about hidden risks in the design that the company is not able to control. The risks are emphasized particularly due to the lack of sufficient prototyping. On the other hand, risk is innate in the business. Hence, the question is more about how big risks the company is willing to take and capable of bearing.

4.3 Communication

Communication between the players in the market is important. It seems that this self-evident fact is still not properly recognized and understood in the companies. The shared IT systems notwithstanding, the distance between the design and manufacturing departments is long. On the other hand, concurrent engineering is not in an efficient use. The rapid development of new technologies has lead to situations in which the professionals of different disciplines do not share the same terminology, which causes misunderstandings. This can bring about reluctance to cooperate among the specialists, and the in-house know-how from different disciplines is not utilized to the full extent.

4.4 Global manufacturing

Today many companies are searching for new opportunities by means of global manufacturing. There are two main drivers for this: the less costly labor rates in the emerging economies, and the proximity of large market areas.

[1] C_DFMA Researcher workshop held at Tampere University of Technology in January 11-12, 2007. Chairman: Professor Asko Riitahuhta.

[2] By this word we mean that the product is producible, i.e. capable of being produced under the specified circumstances.

The conceptual solutions intended for the global manufacturing calls for new understanding. The traditional concepts, when realized under a totally different infrastructure, become easily too costly. It seems that the companies are not aware of the behavior of cost elements in different cultures well enough, or how the product's conceptual features contribute to its producibility. Co-operation between the designers and the purchasers is important, particularly in a situation in which a company is starting the global manufacturing and is validating the local suppliers.

As a consequence of outsourcing the manufacturing activities, the production-related know-how is migrating away from the companies. If the company does not carry on manufacturing itself it will not possess the related know-how later. This results easily in an inefficient co-operation with the new manufacturers or may even lead to conflicts of interests.

It seems than the companies do not plan the mutual activities and operations with their suppliers early enough, which makes it difficult to build efficient partnerships. It takes a considerable time to learn to manage the complex networks in a new environment and to understand the hidden commitments and dependencies. The local suppliers may prefer their own technology as a solution to every application, even though better alternatives might be available.

In general, the companies do not practice the conceptual design, which oversteps their boundaries.

4.5 Summary and further questions

There is not a systematic method available for estimating concepts in all the important dimensions. This problem is emphasized in the decentralized production environments. Global indicators or criteria to help the companies in estimating the concepts' success are not at disposal or they are too difficult to adopt.

These facts raise further questions: How to organize the selection process for concepts, which takes also producibility into account? How precise should the concept be to enable a proper estimation? Could it be possible to build a selection process for various precision levels of concepts? What features should the concepts include and how to map them to the various precision levels? How to find a commensurable measuring system for different concepts? What does a development process of a successful concept look like?

The rapidly changing situations in the market call for prompt responses from the companies. This influences the product development projects, in particular. The increasing number of optional concepts calls for an efficient revision management. The estimation and selection of concepts are inefficient today, which makes it also difficult to manage the potential risks.

5 PRODUCT DEVELOPMENT

5.1 Conceptualization

Conceptual design or conceptualization is generally considered crucial for the design process because during this phase the basis for many properties of the (future) technical system is fixed. Hubka [9] represents the conceptual design as a distinct phase in a procedural model of design process, in which the technical system's anatomical structure is established. It is a sub-process of the general design process, which starts from the design specification and ends in the optimal concept. Conceptual design incorporates two sub-processes, which can be seen as development loops: the first one is called "establishing the function structure" and the second one "establishing concept".

5.2 Design process

Product development can be presented with a model of consecutive phases. The processes include stages and gates for the decision-making to continue or to stop the development efforts [3], [8]. Generally these models apply to the development of new products, which starts from the market need (demand pull). These models can help to structure the processes, which aim to utilize the new innovations (technology push). The product innovations typically originate in the beginning of the process.

However, the majority of product development activities in the industry aim to improve the existing products. In these cases the current development process models are less applicable.

In Figure 2 we see the life cycles of three product revisions, which usually incorporate an upgrade in performance (such as power output), new functionalities, or enhanced life cycle properties. Each revision calls also for a small-scale development project with its own project plan. Evidently, each development project can be separated into the clarification of task, the conceptual design, the embodiment design, and the detailed design, as presented in [4]. From the organizational point of view it is desirable to keep the design load even and concentrate on each development project at a time. Planning and control would be facilitated by means of a structured process-based approach, which allows for a controlled overlapping of design phases: in this way the existing concepts are transferred from one development cycle to the next. Nevertheless, in reality the time for launching the new revisions is not straightforward. It naturally depends on the market situation and on the chosen strategy.

The beginning of a design process description is based on generating a product specification and creating a functional structure. This principle focuses on the product's mechanical realization and treats other technological disciplines less relevant from the viewpoint of product's main functionality. This has lead to a situation, in which the product specifications are separated into technological disciplines and divided into blocks (or chunks) within the disciplines. Even though this separation through partial specifications is a mean to reduce and manage the complexity, it adds distance between the original use and functionality of the product. Once the separation is done, the interaction and integration with and between the systems have disappeared.

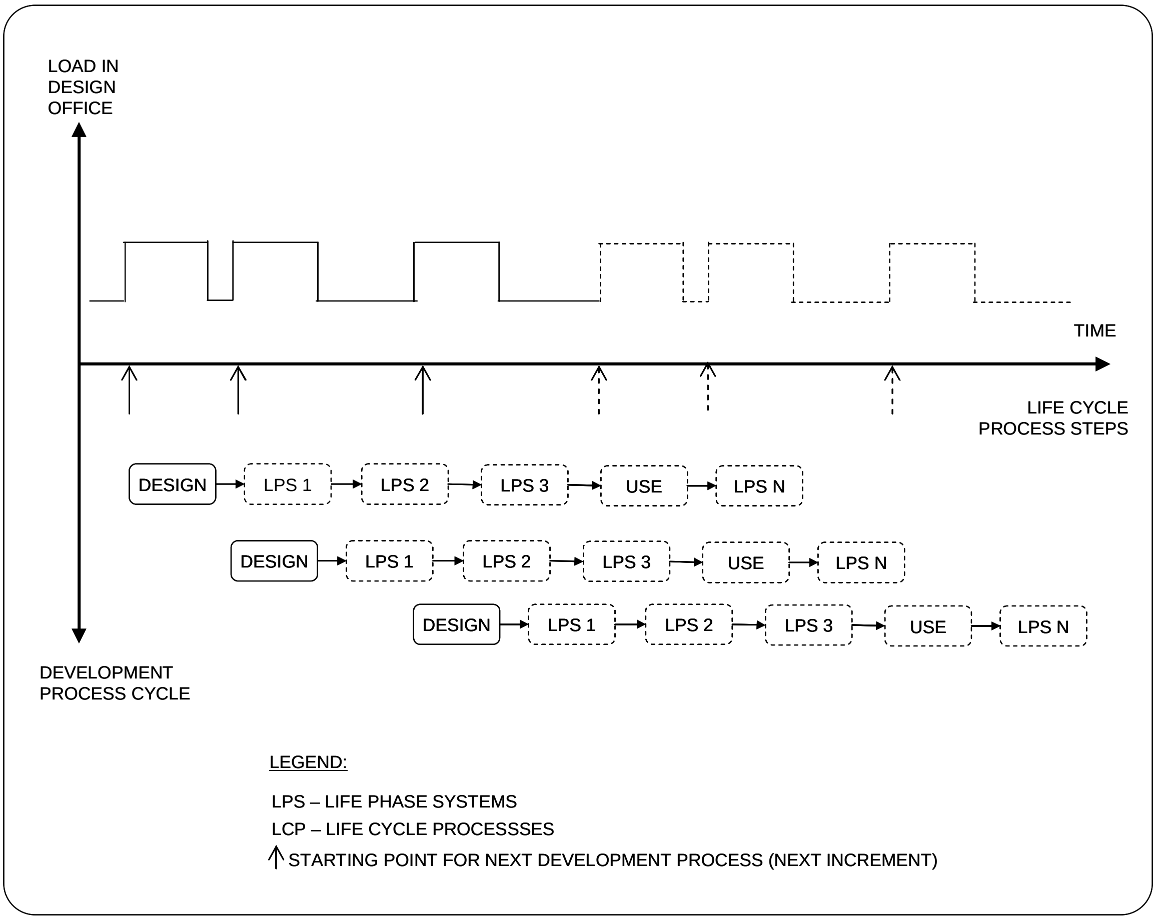

Figure 2: The incremental design process, in which each cycle improves the functionality or life cycle properties of the product

5.3 Cost estimation[3]

Cost estimation is difficult to perform at the conceptual phase of the product development. Actually, we can argue about if it is even possible. The cost estimation of new concepts is performed at the part domain. The premise for cost estimation is often based on historical cost data, which is stored inside the company or which is available from its suppliers.

[3] Presented and discussed in the C_DFMA Researcher workshop held at Tampere University of Technology in November 29-30, and December 1, 2005. Chairman: Professor Asko Riitahuhta.

At the conceptual phase the organ structure is usually known, and sometimes also chunks of the part structure. This means that the materials and the principal dimensions are available to perform the cost estimation. However, the organ structure does not have any materialization, which means that the solution elements from the previous product generations are used as reference. Their costs are based on post-calculations and on the features of the old design.

In the rapidly changing situations also new revisions and/or variations must be generated frequently. This leads to a proliferation of alternative concepts, which increases the work of estimation. Also, as the variations become numerous within the product family, the decrease of batch sizes, the increase of stock items and the management of supply chain raise new cost elements under consideration. Thus, in the fast-moving market the premise for the concept selection becomes easily unclear and makes it difficult to compare the alternative concepts.

5.4 Concept generation by cost pressure

The companies are faced with an increasing cost pressure. As a consequence, the cost aspect is also becoming more important in the conceptual phase. The existing products are subjected to cost reduction projects, which easily spur into reusing the current solution elements without striving to find new ones.

The life cycle properties are improved by introducing conceptual aspects that differentiate the product in their use context [2]. This kind of development concentrates on the product's part domain. The product can be decomposed into subsystems with well-defined interfaces, thus making it possible to create new concepts for chosen subsystems. The concept or an organ structure does not specify any particular supplier but the designers know the potential suppliers from the product's history and this can subconsciously limit the solution space.

The improvements in functionality call for new concepts and the development takes place in the function and the organ domain. Working on this abstraction level leaves much latitude to the designers to search for new solutions.

6 CURRENT CONCEPT DEVELOPMENT TOOLS

The product innovations are considered to come about in the beginning of the process. However, the majority of product development activities in the industry are aimed to the existing products. Unfortunately only a few methodologies for developing existing products or product concepts have been introduced.

The engineering design literature present product development processes and various tools for abstracting the design task and developing further functional solutions. Within the systematic design process the critical stage is the generation of conceptual design alternatives. Formal design process, like VDI2222, provides inputs, tasks, and outputs for each design phase for controlling the process. In contrast, it does not provide the means for generating solutions. All in all, these processes are primarily aimed at new product development rather than for developing existing products.

Pugh [6] focuses on the systematic design process and distinguishes the differences between static and dynamic designs. The concept is given at the outset of engineering work on static design, in which the generic base has been reached. The product specification is written on the assumption that a few changes, if any, are expected, i.e. the concept is defined prior to the specification. With dynamic design the specification is generated from analyses of the market and the users' needs, and the concept will follow. As the design processes are different, a common risk is to consider most designs static and neglect the new approaches – the design activity should always be aimed to an ultimately static concept, the generic base. Creativity and innovations in design are regarded more as organizational and environmental aspects, where the interdisciplinary view has an important role. On the design methodology Pugh distinguishes the qualitative and the quantitative methods, namely on first group analogy, inversion, attribute listing and T-charts, and non-numerical decision matrices. The decision matrix is named the only purely quantitative method.

Suh [7] formalizes the design process as a mapping between four domains; customer, functional, physical and process domains. Technical system's functionality is the expedient to satisfy the customer requirements and shall be defined in a solution-neutral way. The conceptualization takes place after defining the functional requirements and is described as a mapping process from the functional domain to the physical domain. At this stage, the solution (concept, product architecture) is defined by means of the design parameters. Suh highlights the importance of defining the functional

requirements from the customer requirements in a solution-neutral environment. Different approaches shall be used for improving the existing products and for new innovative products. In search for the design parameters (DPs), while mapping from the functional domain to the physical domain, methods like benchmarking, reverse engineering, QFD, and copying are suggested.
How to represent the technical system is a challenge in case of multi-disciplinary products. Integration should be the primary means in the development work; the design activities should have simultaneous consideration of hardware and software. Different models have been presented to provide a systematic breakdown of the product structure using different views. Models of the system are means to increase the context with the problem, but are generally inadequate with integration between the disciplines.

6.1 Innovations

Following the life cycle of a product, Utterback [10] presents a pattern, which shows how the product and the process innovations follow each other. Periods along the life cycle are namely:

- The fluid phase; great deal of experimentation with product design and operation takes place.
- The transitional phase; major product innovations slow down, product variety gives way for standard designs (dominant design), rate of process innovations speeds up.
- The specific phase; both product and process innovations slow down; focus on costs, volume and capacity, innovations in incremental steps.

Distinction between the types of innovations follows the phases and there is a clear transition of intensity from the product innovations towards the process innovations. A later study by Utterback [11] presents a threat to companies, which provide dominant design products. Discontinuous innovations enter the marketplace, either enhancing or destroying the competence. Typically the discontinuous innovations are introduced by established companies, whereas discontinuous product innovations are introduced mainly outside the existing companies. Process innovations are introduced equally inside and outside.
In the industry, the products, which have reached a specific phase in their life cycle, bring often the majority of the cash flow. These products provide the backbone of financing the new product developments and therefore their contribution margin is under a careful follow-up. The established organizations in companies reinforce their capabilities with improvements on the existing products. Henderson and Clark [12] present four types of innovative products:

- Incremental, generated among products at dominant design phase
- Modular, generated among products with dominant products architecture
- Architectural, re-organisation of existing components
- Radical, initiated by new technology

Distinction between the types of innovations may provide some support, explaining in what format and how the innovations may appear. However, from the designer's point of view, main differentiation between the innovations is based on the solution's realization: the new solution is either done differently or done better.
One example of a systematic innovation theory is TRIZ, developed by Altshuller. Within this theory, a substance-field analysis serves as an abstracting model and as a tool to generate innovative "zero sacrifice" solutions, utilising contradictions of the system. The method is at its best in applications in which either a physical or a chemical environment (field) exists in the system. Despite the wide acceptance of the theory, the developers with modern industrial systems may find this methodology laborious or less applicable.

6.2 Product life cycle and development

Another view on the needs and opportunities of the product development with initiation from the feedback of the product life cycle is presented in Figure 3. In this presentation the different types of development and innovation processes can be identified and the methodology and assessments can be proposed. Generally the creation of product innovations is considered to take place during the development phase by the design engineers. However, in utilizing the CE (concurrent engineering) and DFx principles (x presenting for example configuration, modularisation, manufacture and assembly, and life cycle), the people from the company's various functions participate in the development process and the innovations are no longer the design engineers' exclusive right. Different sources can contribute to the incubation of seeds and shed light on various aspects of product innovations.

We can find in the literature a lot of examples, in which great (or radical) innovations have come about almost randomly by hit and miss or after a maturation process of years. What is common to these cases is that each has been considered unique and concluded that no systematic approach can be applied because each problem is different, [13].

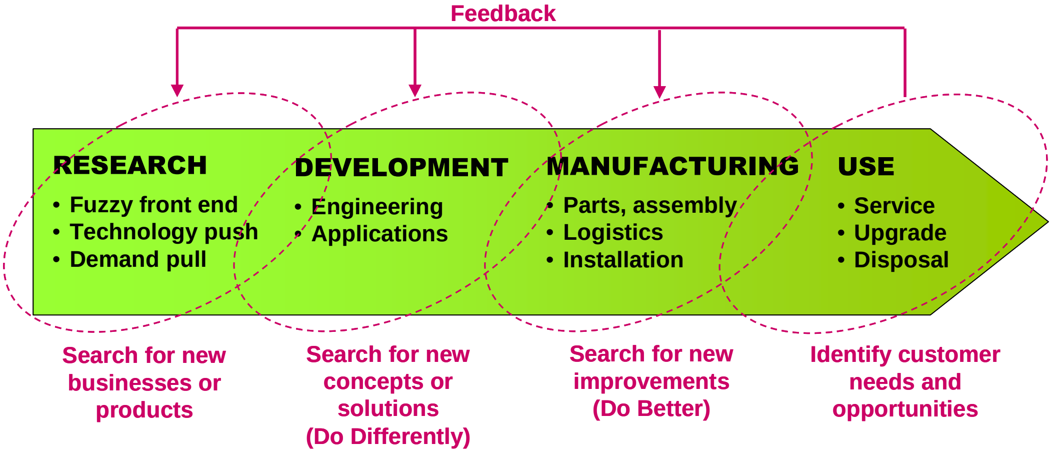

Figure 3. Product development process along the product's life cycle, with the feedback mechanisms.

7 TOWARDS THE NEEDS IN THE INDUSTRY

A systematic engineering and design process is essential to ensure a requirement-driven specification, conception, design, and project execution in the planned schedule and costs. However, the systematic process itself does not generate innovative solutions nor support in finding them. More often the practical problem is not in the developing or improving concepts further on, but in generating the seeds for new ideas.

Many models of design processes are based on successive steps in which the customer requirements are transformed into the functional requirements and further on to the solutions. The definition of functional requirements is essential in the process of new product development, if any previous product does not exist to cope with. However, this is not a typical case in the industry - more often the development activities are focused on the existing products.

As shown in several studies, the degree of innovations along the product's life cycle follows a common path. The strong development stage with numerous innovations is followed by a significant decrease of product innovations. The product design has reached its maturity level, called either the dominant or the static design. At that stage the technical solution is very alike between the manufacturers from the viewpoint of the main functional requirements of the product. Studies also show that the maturity of the design forwards the development activities to the manufacturing processes, mainly driven by the cost pressure.

Models of the technical systems reflect the linear design sequence, in which the product requirements are transformed into a functional structure. This working sequence has an assumption, that the product functionality is satisfied by the sum of different sub-functions. Some design processes even suggest that the functional requirements and the design parameters should match in order to reach an uncoupled design, which supports further decomposition of the functions. This working principle has its merits in the form of robustness and stability, but it provides no room for innovations.

A new approach for developing innovative solutions for the existing concepts requires something to catalyze innovations. During the incremental development the information on how the functionality is delivered can be utilized, in addition to the known structure and design parameters. The challenge of the development teams is to cope with different disciplines and their integration in the machine system.

How should the different information of a technical system be presented or modeled in order to provide directions for a systematic idea generation and finding seeds towards innovations? A rational approach indicates that a systematic way of working can be found, which provides a context from the developed system and stimulates creative thinking, resulting in seeds for the further development.

8 NEW APPROACH FOR CONCEPT DEVELOPMENT

In this Chapter we sketch the new approach for a concept development, contrasting the origination process with the typical ones found in the literature. For the sake of simplicity we illustrate the processes in five steps along a common time line, which depicts the life cycle of the technical system being developed, see Figure 4.

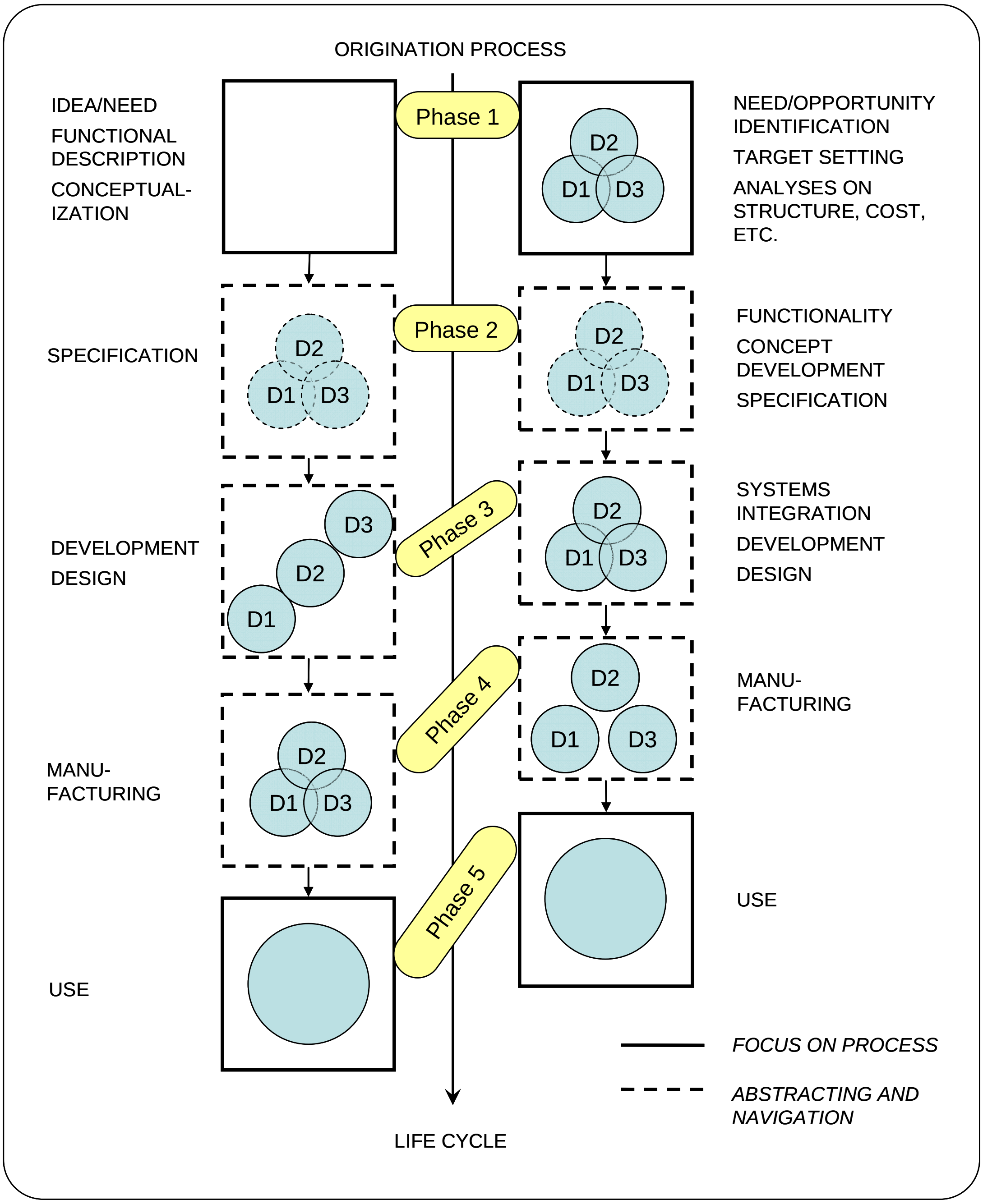

Figure 4. The origination processes seen as part of the life cycle of a technical system. The traditional approach is on the left and the new approach is on the right. D1, D2, and D3 mean different disciplines.

8.1 Traditional approach

In the traditional origination process the concept generation is based on the foreseen life cycle contexts, like manufacturing, use, and service. The product is regarded as an entirety, without any specific structure, parts, or technologies.

The functional description is then developed into a design specification, which can suggest alternative technologies. There is a hidden risk in this phase to envision the functionality only as a resultant of sub-functions and to exclude the entirety.

In the third phase the development work is allocated to the development teams, which are formed according to the traditional disciplines: mechanical, electrical, software, etc. Manufacturing follows the same discipline-wise split, thus in phase 4 the product is regarded as a compilation of different disciplines without the overall functionality. In the final phase, when the product is being used, the different disciplines merge into an entirety and the overall functionality becomes dominant.

8.2 New approach

The new approach assumes a technical system that already exists in the beginning. This assumption is justified in view of technical evolution, in which the new products are based on a wide-ranging reuse of existing solution elements. The concepts related to the different disciplines have been proven along this evolution; only the use concept needs to be sketched and worked out. We underscore that this assumption does not hold true for break-through products, which are based on totally new technologies or physical phenomena (referring to the innovation levels 4 and 5 in Altshuller’s scale).

The first phase of origination process outlines the future use context, by identifying the needs and opportunities on the one hand and setting business targets on the other hand. For verifying the usefulness of the existing concepts of different disciplines a structural analysis and cost estimation are recommended.

In phase 2 the product’s functionality and functional chains can be seen as an integration of various technologies and the improved concepts are built on and around them. The further development work takes place in phase 3, in which the sub-technologies are matched to form a consistent system.

Today the global manufacturing poses new challenges to the industrial companies. Therefore we are inclined to present phase 4 as a decentralized manufacturing process, in which the chunks of various disciplines are manufactured in the most suitable (often also most cost-effective) factory. However, we claim that the end result, the product, is still seen by the customer primarily as a functional entirety.

Because this new approach is based on an existing product, the development cycle can be repeated every time a new feature or functionality is needed for the product. This enables us to focus only on the aspects that really are relevant in the future use context. Every development cycle involves an innovation (ranging from the level 1 to 3 in Altshuller’s scale). Therefore we can also call this new approach an incremental innovation process.

8.3 Discussion

Judged by our industrial experience we claim that the traditional approach focuses more on generating concepts for creation of new products and less on reusing the concepts for improvement of existing products. The new approach as outlined above is based on proven solution elements and focuses on aspects that are relevant in the use context.

We do not set these approaches against each other but rather see them as complements. However, as can be concluded from the Figure 4, the new approach allows for shorter development cycles for the product because of proven concepts of various disciplines. In addition, referring to the Figure 2, the use of resources can be planned and controlled better and thus ensure a smooth load to engineering designers. This has also a positive impact on creative thinking.

8.4 Field tests and further studies

The basic elements of this new approach have been used in the selected Finland-based industrial companies, which are operating globally. Our findings have been discussed and debated in the C_DFMA researcher workshops. Even though we have already got some field experience, we agree that more industrial cases, especially from different branches, are needed in order to develop this new approach into a more formal tool. The findings and results will be further discussed in our future articles.

9 CONCLUSIONS

The industrial companies are not utilizing conceptual thinking to the full extent, relying on the traditional methodologies of product development. The fast-moving market calls for a quick response from the companies in the form of improved product life cycle properties or new functionalities. A

wide-spread problem in the industry is the lack of such a development process that could help the companies in catalyzing new innovations. The companies have also problems in finding the new conceptual aspects in their existing products, which impedes them from focusing their development efforts accordingly.
The traditional design process for concept generation does not provide a sufficient support to the development of existing products or designs. Continuous improvement is important both in order to meet the future product requirements and to streamline the origination process. Therefore, a new approach is needed to allow for a development process, which makes it possible to introduce the improvements incrementally.
The main outcome of this study is the new approach that helps the companies in generating new concepts for the existing products in an incremental way. This approach takes into account the market requirements, the technology opportunities, and the product and process meetings along the life cycle. To develop this approach into a formal design tool, further field tests and cases from various branches are needed.

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