Challenges for Design Management

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ABSTRACT

The globalization of the markets, increasing complexity and diversification of products as well as product and process innovations as central factors of business competition have forced companies to create new strategies of product development. This article examines how today's companies have brought forth the necessary technical preconditions in the CAD environment for the application of virtual simulation and verification techniques. In addition to evaluation of contemporary techniques, the article is devoted to possible causes of missing basic conditions. These remarks will be concluded with prospects in future challenges of the product development.

Keywords: CAD, product development, knowledge based engineering, design methodology.

1. INTRODUCTION

The wide-ranging move-in of the 3D CAD technology in design and development departments more than 10 years ago brought apparently unlimited potentials of an accelerated and cost-efficient product development to the manufacturing companies. After years of continuous progression of the CAD technology it is time to recapitulate efficient 3D product modeling for the implementation of company-specific integrations of data and functions into the product development process.

The evolution of the past few years has figured out that global competition and acceleration of the technological progress as well as local cost structures have increasingly gained a decisive influence on the companies. Therefore new software solutions and conceptual approaches for an accelerated and more efficient product development process had to be found. The reforming approach of the *Integrated Product Development (IPD)* represented, as is known, an effort to overcome the problems of the highly interdisciplinary product development [7]. This concept stands for a goal-oriented combination of methodical, organizational and technical methods to realize the product development process, which ideally is characterized by a short developmental period, low manufacturing costs and high product quality. Factors of success of this approach are on the one hand team-oriented and multidisciplinary methods of operation inside the own field of company as well as in cooperation with suppliers and customers. On the other hand a fulfilled paradigm changeover towards a holistic consideration of the whole product life cycle will lead to success as well. Furthermore, adapted organizational structures ensure a wide parallelization of process steps in terms of the *Simultaneous/Concurrent Engineering*. The adequate selection of effective tools and methods of the computer-based information technology finally contributes importantly to the successful implementation of the integrated product development in a company. In doing so, the components of modern product development (Fig. 1) hold a high dose of potential to additionally accelerate and optimize the product development.

What appears absolutely academical is in fact rarely trivial to realize. Therefore it is not astonishing that numerous companies try in vain to utilize the synergy effect despite extensive efforts to improve the product development process. A nonexisting master plan or insufficient utilization of available corporate resources finally avoids the economic progress. It is not sufficient to reorganize sub-processes of the product development if the realization turns out isolated and without consideration of associated sub-tasks of the product development. Rather than that, the potentials of optimization, which are present in every company division, have to be detected and synchronized with holistic consideration. Withal, according to experience especially the adjustment of product defining sub-processes will cause difficulties. Using the example of a cast design, Fig. 2 points out, that even individual components include manifold dependencies between the necessary, applicatively generated partial models. However, in practice these dependencies rarely are reflected in continuously linked digital product models.

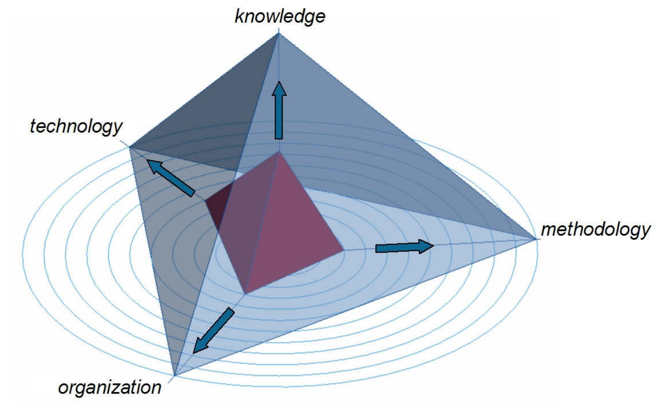

Fig. 1: Potentials in the product development process.

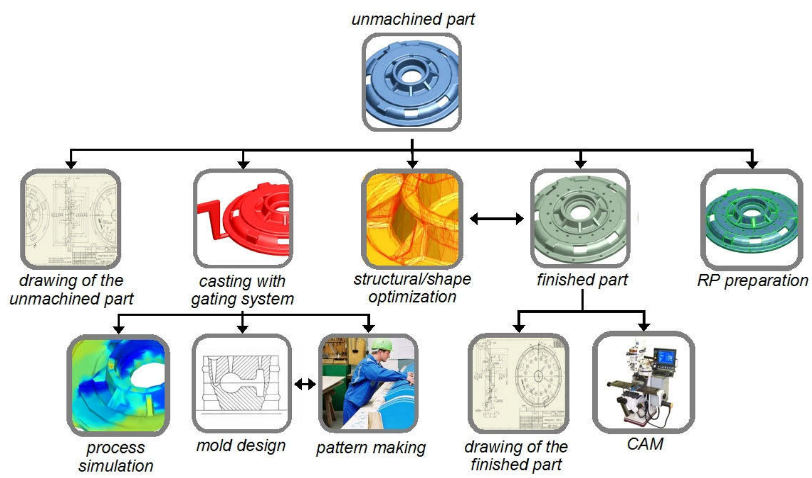

Fig. 2: Interdependencies between partial models.

2. MODERNIZATION OF CAD PROCESSES

Particularly in the phase of design, thus in an early stage of the product design, where the lion's share of the costs (70 – 80%) will be defined, it is necessary to ably take advantage of the potential of professional CAD technology to rationalize the design and manufacturing processes. A couple of companies already spotted this necessity in the mid 90s and consequentially expanded the usage of CAD data to adjacent and subsequent processes by establishing the 3D CAD technology in the digital chain of added-value (Fig. 3). Until 5 years ago, every second utilized CAD system worked 2D oriented. Up to now, the number of 3D systems rose steadily and according to investment plans of the users, in near future it will rise up to 90% (source: Roschiwal + Partner GmbH). That points up the development to volume-oriented 3D modeling and a renunciation of the "digital tubular drawing pen". This trend is basically justified in the auspicious consistency of 3D CAD data, which announces an acceleration of the steps of development for the whole product life cycle.

There is no question about the fact that various companies are aware of the importance of modern 3D CAD modeling as a factor of success to maintain competitiveness. However, the imagination of possible potentials of benefit is too imprecise. Often the unsteadiness is caused by labor-intensive and time-consuming measures of strategy. In addition to adequate corporate-harmonized strategies of implementation and utilization, techniques have to be developed, which are optimized with respect to the development tasks and which utilize the offered CAD power spectrum [12]. Furthermore, an efficient implementation of 3D CAD technology usually is associated with a new conception of the product development process. In this connection, under certain conditions the IT environment has to be reconfigured as well (e.g.: implementation of a product data management system, PDM). Regarding the dimensions of preliminary work which has to be done, justifiably the following question raises: To what extent and, above all, at which time the advantages of an implementation of 3D product modeling in the company will arise? In addition to an acceleration of CAD modeling, the 3D CAD technology represents the fundament of validation and backup of design results (*Finite Elements Method*, multi body dynamics, *Digital Mock-Up*, assembly simulation, *Computational Fluid Dynamics*, *Noise Vibration Harshness*, etc.) based on the master geometry of the product model (see Fig. 4).

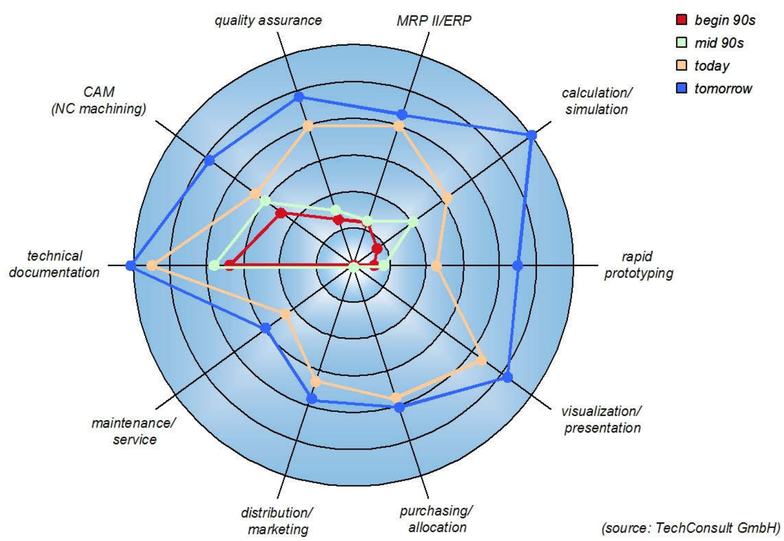

Fig. 3: Changing use of CAD data over the past years.

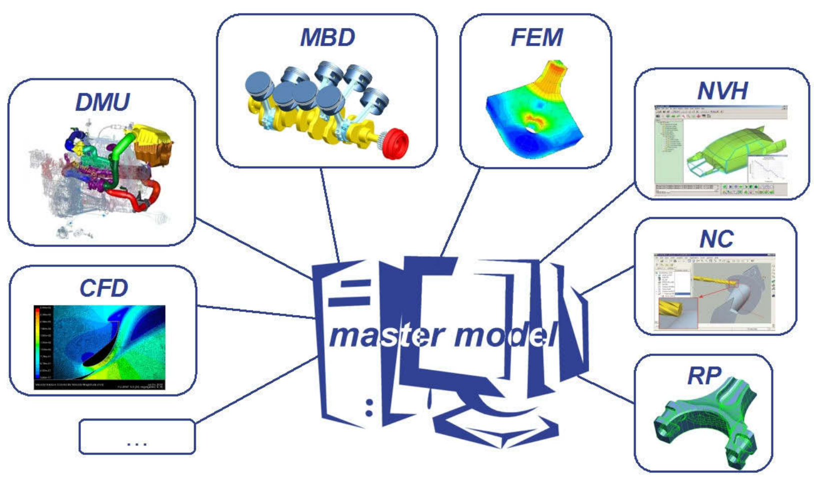

Fig. 4: CAx solutions based on a master model.

Beyond it, the master model can serve as an origin for downstream processes (NC manufacturing, *Rapid Prototyping* [9],[11], casting, etc.) and therefore provides a computer-based CAD/CAM integration [5],[6]. Regarding the break-even point of the migration concept, one has to consider that parts of the comprehensive potential of benefit of a computer-integrated 3D design can only start taking effect at a later date (cp. Fig. 5). Therefore accurate product modeling, considered as integral part of an enterprise-specific master plan, is highly significant for enduring preservation of economic efficiency.

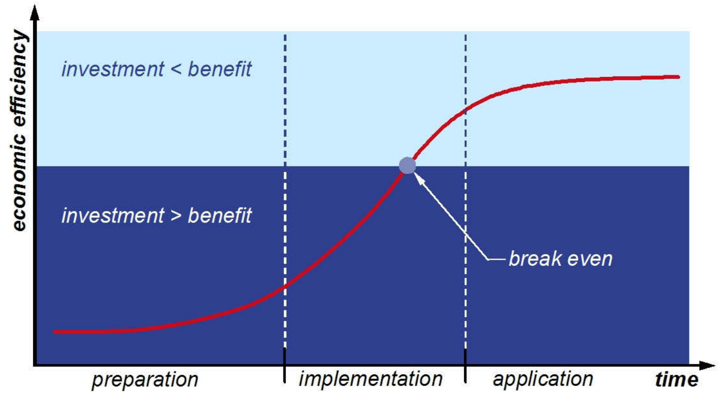

Fig. 5: Investment and benefit of the 3D CAD technology.

3. KNOWLEDGE INTEGRATION IN ENGINEERING PROCESSES

More than ever, information (applied knowledge) has established to a further factor of production. Increasing complexity as well as shrinking innovation cycles of technical products and systems, necessitate considering detailed know-how and special knowledge in the product development process [15],[18]. As a result, for the profitable application it is essential to implement knowledge integration in engineering processes (e.g. CAD) as a part of an associative knowledge and information management whereas the yield is solely ascertained by the completeness and availability of product and process data. For a considerable time, CAD system providers account for the strategic objective of knowledge management to transfer an unstructured random use of knowledge to a structured and goal-oriented exhaustion of knowledge resources. By observing the development of CAD systems it becomes apparent, that in addition to the foundation pillars of modern 3D CAD technology (volume modeling, parametrics) as well as the associated (bidirectional) associativity, the implementation of knowledge oriented components into the design process increasingly gained in importance. That includes, amongst others, feature technology, application programming interface (API) and knowledge based design steps (*Knowledge Based Engineering* – KBE). These components, in the meantime belonging to the standard equipment of professional 3D CAD systems, are built up consecutively and provide a powerful tool for efficient 3D product modeling (Fig. 6).

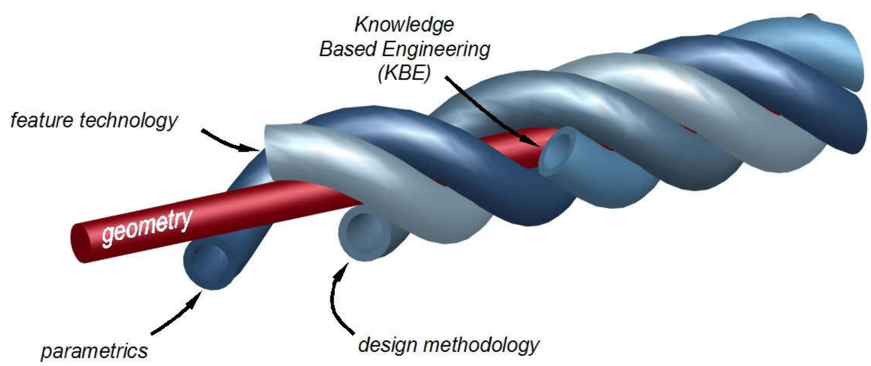

Fig. 6: Development of CAD systems by integration of knowledge processing components.

3.1 High-Order Feature

Feature, as a coalescence of parametrics and/or semantics, support function-oriented product modeling by handling geometry data on the basis of manipulated expertise and assure the possibility of communication between users as well as inside the CAx environment (e.g. CAD/CAM integration) [4]. Frequently recurring design steps (holes, grooves, bearing metals, sections, undercuts, etc.) can be executed (partly) automated with the help of information and integration objects, implemented as user-specific features. Not rarely that leads to a significant reduction of time for modeling. Furthermore, feature based modeling results in standardization of product modeling and consequently to the enhancement of process reliability. By far the biggest advantage of the feature technology is, at a progressive rate, the usage of the deposited product and process relevant information all over the phases of the product life cycle [13],[16]. In the case of successful feature identification and feature transformation, information can even be read out and manipulated in subsequent stages of the product life cycle. In practice the utilization of user-specific feature has already been successfully implemented in numerous companies of different industrial sectors and from today's point of view, it is hard to imagine without (source: actual CAD survey, carried out by the market research institution Marketing Essentials). In this manner, user-defined feature libraries arise in design and development departments, which, in consideration of the company's own specifications and guidelines, provide the designers standardized structural parts with implemented knowledge [13]. While configuring such a company-specific feature library, a profound analysis and definition of the feature content should be carried out by an interdisciplinary team to assure long-term synergy effects [17]. In this context, the following principle applies to a predefinition of the complexity of high-order feature: As much as needed, but as little as possible.

3.2 Knowledge Based Engineering

The technology of Knowledge Based Engineering (KBE) extends feature oriented and parametric-associative product modeling by rule-based modeling techniques, know-how, rules, analysis and checking functions (*model checking*), event-driven routines as well as custom specific optimization processes. These elements of design automation can be integrated in the design process by utilization of the CAD toolkit and available templates. Another elementary utility is the interaction with the help of the application programming interface (API) of the CAD system and the access to the CAD kernel to manipulate the CAD internal description of the geometry and the topology. Adequate structures of knowledge provide combinations of different types of knowledge. In doing so, the choice and respectively the creation of KBE modules is determining for the acquisition, integration and maintenance of knowledge for the knowledgebase [18]. The superficial purpose of application of the KBE technology is a rule-based support and acceleration of the design process by (partially) automated design steps [12]. In addition to the relief for the designing engineer of time consuming routine jobs, with KBE it is possible to fall back on processed know-how to determine violations of design regulations, compliances with product specifications or possible alternatives to design variants. In consideration of company specific model properties, knowledge based designs additionally provide all information required regarding the shape, function and manufacturing of the product for all phases of the product life cycle (Fig. 7).

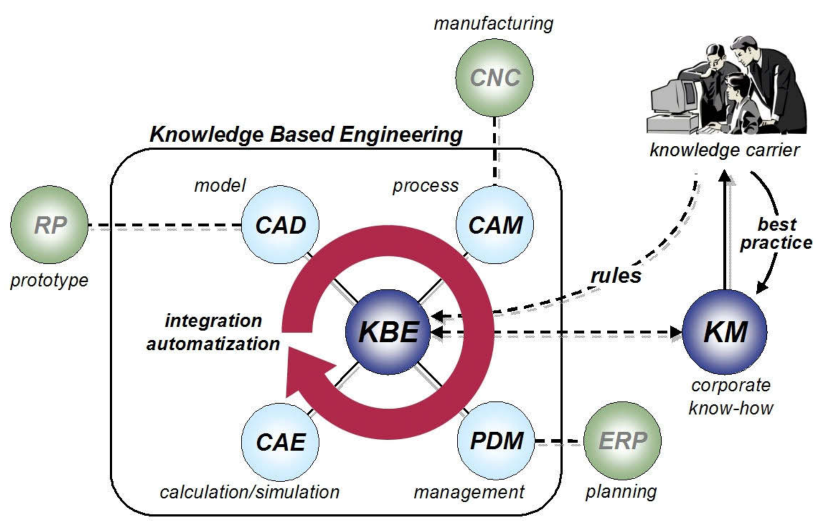

Fig. 7: Integration of KBE in the computer-aided design process.

Whereas numerous companies of the automotive industry and its subcontractors discovered the time-reducing and cost-cutting potentials of the KBE technology, there can be no talk of an area-wide implementation in other lines (source: EM Engineering Methods AG). On the one hand, the potentials of use have to be discovered and on the other hand, the technical, organizational and methodical preconditions have to be established. Factor of success of the knowledge based design is a goal-oriented, systematical implementation of KBE technology by a multi disciplinary project team. The knowledge based engineering process itself is characterized by three phases:

1. collection and documentation of knowledge,
2. structuring of knowledge in a knowledge base,
3. interaction between system and user.

Therefore the acquisition and structured provision of knowledge is the biggest challenge and most often the obstacle for small and medium-sized enterprises at the same time. The significant difference between parametric, feature-oriented modeling and KBE is the method to the design result. Whereas parametrics is used to modify/optimize generated geometry with the help of rules and dependencies (geometrical constraints, relations, etc.) subsequently, the handling of basic conditions provides the basis of geometry creation in the case of knowledge based design. According to this, the use of a knowledge base using rules and verifications finally results in the geometry of the CAD model.

3.3 Engineering Systems with PLM-Concept

Professional CAD systems recently advanced to systems with an integrated PLM-concept (*PLM – Product Lifecycle Management)* and represent to applicable extent big parts of the product development process. Today's CAD systems frequently provide modules for implementation of KBE to integrate the knowledge processes in 3D product modeling. By this means, rules can directly be applied to the model geometry and rule-based modifications can instantaneously be visualized. Beyond it, the trend leads to augmented integration of multidisciplinary engineering processes [14]. For example on the basis of the created 3D models, vibration and stress analyses up to kinematical simulations can be accomplished. Actual developments increasingly deal with the integration and simulation of mechatronical systems. Because of exploding data volume the development will rather focus on the linkage between 3D CAD data and a mechatronical functional model than on the generation of a totally integrated digital model with all dependencies regarding the electrical equipment including controller and mechanical layout (source: AUCOTEC). The holistic optimization of these systems, as the simulation of multi body systems or complex machines, actually is pushed especially in larger companies with capital expenditure. Especially in the automotive sector, the implementation of mechanical and electrical developments poses a big challenge. As a differentiation criterion, in the automotive competition it is essential to integrate these cost defining development steps into the CAx environment with the help of already existing data models.

4. VIRTUALITY IN THE PRODUCT DEVELOPMENT PROCESS

Generally, it is worthwhile to aim at continuous process chains which exceed the classic CAD/CAM integration. In this case, we talk of *Virtual Product Development*.

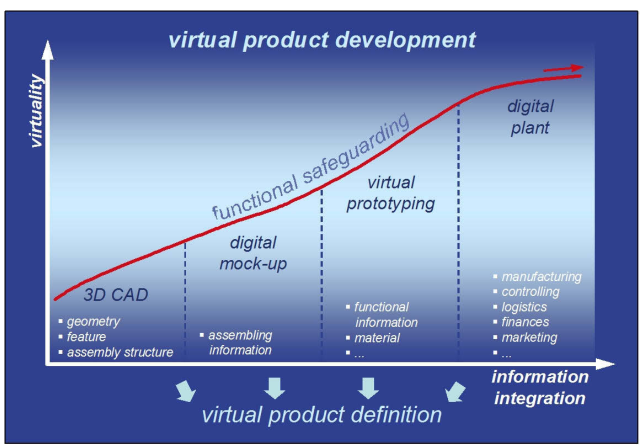

Fig. 8: Tendencies of virtual product development (according to R. Anderl).

Computer-aided business processes are consolidated whereas a completive and continuous data model serves as the basis of these process steps. Fig. 8 reflects the tendencies of development of the virtual product development. In addition to the 3D CAD technology, which is the fundament of a modern and rationalizing product synthesis, companies actually focus on functional safeguarding of the results of development [3]. Digital test models (*DMU – Digital Mock-Up*), which represent the structure of the product as well as their accurate position of the geometry, enable a multidisciplinary presentation of the assembling process (*Design in Context*) as mounting, demounting, view and collision analyses. The so called *Virtual Prototyping* upgrades DMU to functional and production relevant information. The superficial aim of the technology is the optimization of products and processes as far as possible as well as the economization of substantial test prototypes [1]. Continuative development deals with the simulation of complex business operations to accelerate planning processes (*Digital Plant*). In addition to the reduction of *Time-to-Market*, with that kind of foresighted production scheduling it is possible to increase the quality of planning and to optimize the planning of variants.

Up to now mostly major enterprises successfully simulate mechanical dependencies with DMU (source: actual CAD survey, carried out by the market research institution Marketing Essentials). They also have discovered Virtual Prototyping as an efficient technology concept for the optimization of business processes. In contrast, small and medium-sized enterprises (SME) frequently fail because of insufficient preconditions [8]. Without 3D CAD, there is no way to think of a virtual product development. The application of the digital plant as presently most comprehensive and most complex type of virtual safeguarding, in fact does not play a major role for the SME. Also in that case, the precursors are major enterprises of the automotive, aviation and electronic industry as well as plant engineering and construction.

5. CONCLUSIONS AND FUTURE PROSPECTS

The development in recent years emphasizes, that only the application of future-oriented technologies of product development can maintain the competitive position of today's companies. But therefor necessary preconditions (3D CAD, PDM, KBE, etc.) should have been accomplished up to now. Those companies that do not react to the continuously changing influences today will stand aside the global market economy tomorrow. For this reason, it is essential that the potentials of use of modern information technology will be discovered and that the necessary general framework will be built up in line with a master plan [2],[3]. As a result, the potentials of modern development methods, shown in this article, are supposed to encourage today's companies to reconsider their own business processes critically. The first step to modernization and optimization of the product development is to consider the provided mentioned techniques. That especially applies to the SME. The article should not convey the impression that all introduced techniques and methods are suitable for every company, but first potentials of optimization can be discovered by in-house reviews or in cooperation with service providers/academies. Continuative analyses can subsequently lead to a customized package of methods, applications and technologies.

The pointed question of balance of the implementation of modern methods of product development should be answered much differentiated. Whereas a few companies largely cover the wide spectrum of available tools and concepts, many companies do not, because of the lack of necessary preconditions (source: EM Engineering Methods AG). Those have to be accomplished as soon as possible to be able to benefit from modern concepts and technologies for the provision of product knowledge at an early stage (see Fig. 9), which can lead to maintenance of competitiveness. The integration of product and process specific knowledge in the product model finally enables the transfer of know-how into several corporate divisions and therefore a permanent up-to-date access to object relevant information as well as a reduction of redundant data sets and preparation of subsequent processes [3]. These are the first steps towards Cross Enterprise Engineering (CEE) which supports the global cooperation of internal and external organization units in the course of the transformation of classic product development processes into virtual processes. Furthermore, rule based compliance with industry standards assures process reliability.

In addition to pure utilization of time-reducing and cost-cutting potentials of use, the aspect of innovation becomes more and more important. Successfully implemented product data management provides the opportunity to fall back on centrally stored knowledge of different sources and disciplines and therefore pushes the realization of innovative ideas. The fact that knowledge is never static but subjected to permanent changes, leads to new challenges in the range of the computer-aided product development. Future requirements will be to return new perceptions of the handling of applied knowledge into the development process again.

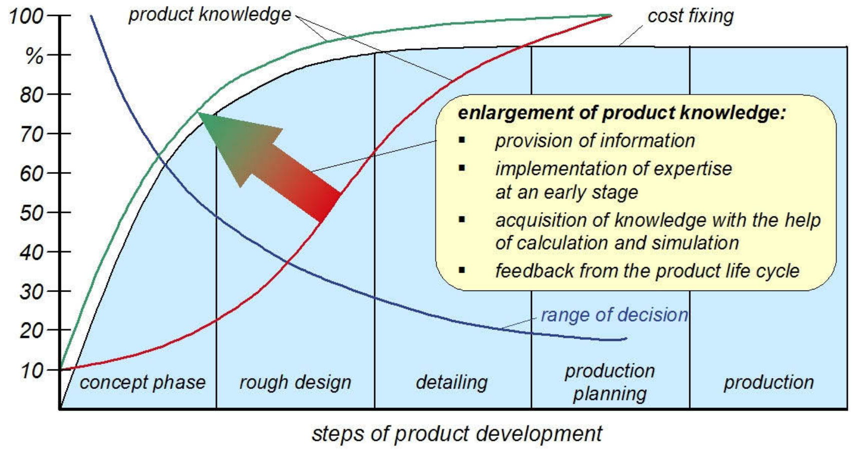

Fig. 9: Provision of product knowledge during the development process (according to BOEING).

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