ANALYSIS OF CURRENT IT SUPPORT FOR PRODUCT DEVELOPMENT PROCESSES

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The purpose of this paper is to settle the claim for a systematic and up-to-date overview of relevant IT support in the area of product development. In the last few decades product development has become an almost entirely digitised process and is therefore dependent on IT support. This evolution was accompanied by a substantial growth of the corresponding software landscape. The range of software products now reaches from specialised niche tools for single task to large software suites offering generic functionalities. We conducted a literature review on product development methodologies and summarised our findings in a process model. On this basis a categorisation pattern for product development software was derived. Existing tool classes were identified through a market analysis and assigned to categories. The outcome is an overview of current software for product development which can be used by developers to compare their software landscape.

Keywords: New product development, IT support, literature review, process models.

1. INTRODUCTION

In almost every industry sector companies have to cope with ever shorter development cycles and increasing technical complexity of development projects [1, 2]. Furthermore, it is often stipulated that an increasing number of design criteria are considered in every development step. These so-called design for X criteria include future production-, maintenance- or recycle-costs as well as product safety, reliability, quality and modular design strategies to ensure flexibility [3, 4]. This means that the entire product lifecycle has to be elaborated throughout the development process. Also, besides tailoring products to regional preferences and regulations, developers also have to cooperate in globally distributed teams [5]. Especially high-tech manufacturers stumble into a dilemma. On the one hand technological progress causes new products getting increasingly complex [6]. On the other hand product lifecycles are getting shorter and shorter [7]. A driving force behind this trend is the competitive environment of markets forcing companies to have new marketable products in their pipeline. This implies, that if future products shall remain at a high level of quality, development process requires additional resources. Under the prevailing circumstances, often several hundred people or even companies are involved in some development projects. The outcome of this is a growing gap between claims and possibilities in product development. The only way to cope with the increasing complexity and other challenges of product development is the extensive utilisation of information technology (IT).

Although performance of the first generation of CAx systems was comparatively low, they already often lead to a major reduction of development time and minimised the amount of mistakes made in the process. In addition to that, modern software tools offer a wide variety of functionality and methods that do not have any counterpart in traditional design methodology. The use of IT support in product development has therefore extended boarders of technical feasibility and gives developers' creativity a wider scope. Besides, simulation software makes it possible to predict more precisely, in how far certain design decisions will affect the future product lifecycle [8]. In this context a huge variety of

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tools has shown up on the product development software landscape over the years. This led us to following research question: How can IT support for product development be categorised and what kind of assistance is realised?

2. RESEARCH METHODOLOGY

From January to April 2010 we conducted a literature review on New Product Development (NPD) processes to identify gaps in current product development methodology [9]. In this research context we identified and analysed 41 process models that all illuminate product development from a different perspective. Comparing the models with each other we were able to segment the generic development process into three development domains (product concept, product design and production design, compare also [10]). Apart of this we differentiate product development management and information management as accompanying processes. Figure 1 illustrates our approach.

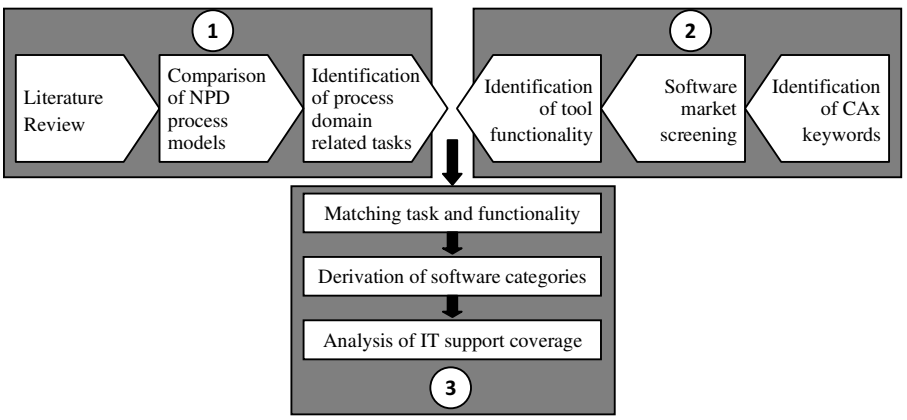

Figure 1. Research approach, Source (own illustration).

To compare IT support tools, we took our former work as a basis for categorising software tools (Figure 1, step 1). We employed this comparison framework for classifying software tools. Subsequently, we accomplished a structured analysis of the software market. For this purpose we screened relevant literature [8, 11–16] to identify product development software related keywords. On this basis we set up a preliminary set of keywords and used the most common search engines (Google, Bing and Yahoo!) for identifying relevant tools. We widened our search scope by adding the most frequent keywords that were used in product descriptions of previously identified tools (Figure 1, step 2). In a next step (Figure 1, step 3) we matched the functionality of each IT tool to the tasks of the process. Based on this comparison we derived the division of software categories and analysed in how far the development process is supported by IT.

3. THE GENERIC DEVELOPMENT PROCESS

The primary difference among different NPD process models is the degree of resolution in which the process is described. The spectrum reaches from micro-logic perspectives that describe elementary activities to models, which rather focus on the macro-logic of the entire process [17]. We compared different process models using a unified comparison framework [9]. This was developed on the basis of Krishnan & Ulrich's work [10]. The main finding of this step was that the various stages described in literature formed a number of clusters containing analogous task specifications. According to [10], we generalised these clusters to three product development domains (Product Concept, Product Design and Production Design) summarising the core process. Figure 2 sketches a generic development process derived from the results of our literature review.

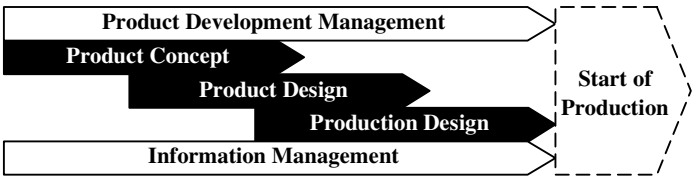

Figure 2. The generic development process. *Source* (own illustration according to [9]).

Product Concept includes all tasks related to product conception such as marketing, requirements management or idea illustration. As the second observable domain, Product Design comprises engineering and testing tasks, which alternate in iterative loops until a satisfying design is found [18]. The third domain of Production Design includes activities dealing with the upcoming production. In addition to that, two supporting processes can be described. In consensus with Krishnan and Ulrich [10] we identified Product Development Management and Information Management as two major support processes.

4. CENSUS OF SOFTWARE TOOLS

We studied literature on computer aided development and its sub disciplines (Computer Aided x, CAx) to identify relevant keywords for software market screening. Vajna *et al.* [8] for example illustrate the use of software in product development depended on the progress of the project and the complexity of the product. In this model Product Data Management (PDM) and Enterprise Ressource Planning (ERP) serve as basic tools along the entire development process independent. During early development stages, tools for conception support come into operation. Computer Aided Design and Engineering (CAD, CAE) are building blocks for the following design stage. When a final design is found, Computer Aided (Process) Planning (CAP or CAPP) and Computer Aided Manufacturing (CAM) help to prepare mass production. As a result of this examination we got the following table which gives an overview of all keywords that were then used in the software census.

Table 1. List of keywords for Software Market Screening.

keyword	*keyword*	*keyword*
Computer Aided Design (CAD)	Computer Aided Innovation (CAI)	Computer Aided Quality (CAQ)
Computer Aided Manufacturing (CAM)	Computer Aided Industry Design (CAID)	Knowledge Management System (KMS)
Product Data Management (PDM)	Computer Aided Planning (CAP)	Collaborative Design System (CDS)
Computer Aided Process Planning (CAPP)	Product Lifecycle Management (PLM)	Integrated Development Environment (IDE)
Computer Supported Cooperative Work (CSCW)	Electronic Design Automation (EDA)	Engineering Data Management (EDM)
Requirements Engineering (RE)	Requirements Management (RM)	Computer Aided Engineering (CAE)
Virtual Factory	Project Management (PM)	Electronic CAD (eCAD)
Mechanic CAD (mCAD)	Digital Mock-Up (DMU)	Collaboration Support System (CSS)
Innovation Communities	Open Innovation (OI)	Enterprise Resource Planning (ERP)

5. RESULTS

Having screened the software market, we analysed the functionality of 52 software tools (e. g. CATIA®, Tecnomatix®, SAP Business Suite®, Goldfire® or DOORS®) as stated by the vendor. Then we compared the functions offered to the tasks that were identified in each process domain during

research on NPD process models. Table 2 links the respective development stages and domains to the corresponding IT system classes, represented by keywords that were used for describing the tools. In the next sections we highlight characteristics of the IT support in every process domain in detail.

Table 2. Framework for Software Classification.

Development Process Domains		Corresponding IT System Classes
Product Concept	Product Placement	CAI, Innovation Communities, OI
	Product Requirements	RE, RM
	Product Draft	CAID, CAI, DMU
Product Design	Engineering	CAD, IDE, EDA, mCAD, eCAD
	Testing	CAE, CAD, IDE, EDA, mCAD, eCAD
Production Design	Process Design	CAPP, CAP, Virtual Factory, NC
	Organisation and Supply	CAM, SCM tools, ERP
Product Development Management		PM, CAQ, ERP
Information Management		PDM, PLM, KMS, CSCW, CSS, CDS

5.1. IT support for Product Concept

5.1.1. Product Placement

Analysis of customer needs and product utilisation patterns is in many cases an essential part at the beginning of NPD. To collect this kind of information, companies apply IT supported market research techniques like mining of customer data or integrating customers directly by using open innovation platforms [19]. When a company has detailed knowledge about market segments and preferences of its customers, it can align product concepts with market needs. In this context IT systems play an important role in prospecting for ideas globally as they offer product stakeholders a possibility to communicate suggestions or desires to developers. The advantage IT can offer is contact with many people at the same time at low costs by using adequate platforms like communities for innovations [20, 21].

5.1.2. Product Requirements

Tools for supporting Requirements Engineering & Management (RE&M) are particularly known from software engineering, where developers traditionally have to systemise a variety of abstract and often contrary requirements [22]. In the manufacturing industry mainly big corporations have realised, that specialised tools offer many advantages in complex development projects. The target of RE&M tools is to provide a structured survey of the manifold requirements along the product lifecycle and to identify target conflicts. As requirement conflicts are often resolved by offering multiple product configurations and variants, those systems need to be capable of managing a system of interdependent requirements for different variants and configurations [23, 24].

5.1.3. Product Draft

Product drafting is supported by two different kinds of systems. While CAI systems support engineers with the development of a functional concept, designers use CAID systems and Digital Mock-Up for visualising the product concept. CAI systems offer structured innovation methods such as Value Engineering or TRIZ[a] and provide useful tools like search in patent databases. Furthermore they help developer to predict the direction of development along the innovation process, to create patent screens and to discover yet unoccupied market niches. Anticipatory error detection helps to improve the product and ensure quality. Since CAI systems offer structured methodologies, developers are guided throughout the process and NPD becomes easier to control [25].

[a] (=The theory of solving inventor's problems)

5.2. IT support for Product Design

Product design is not only about physical design, but also about electronics and software. Accordingly, design and testing processes take place in all domains, both individually and in an integrated way. Current systems do no longer offer only engineering or testing functionality, but combine both in one integrated solution [12]. Experts expect an increase in the share of value added electronic components. The more electronic components are used in the products, the greater the development effort in this area. CAD of electronic components (eCAD, EDA) is therefore an integral part of product development. eCAD systems support developers in the creation of control schematics, function and wiring diagrams as well as layout of circuits. Moreover, they are also capable of simulating product electronics [26].

The analysis of physical interrelationships by means of calculations is one of the main tasks of an engineer. Before the advent of the computer, engineers used traditional methods of calculation in the form of analytical, tabular or empirical laws. These procedures are still applied, but today they are usually embedded in software systems. Major mathematical software systems are for example Maple®, Mathematica®, or spreadsheet software such as MS Excel® [27]. In contrast to early systems for simulation, usability and flexibility of those tools has evolved enormously. While programs of the first generations were largely single-purpose tools with their calculation patterns being hard-coded and allowing only certain input values, modern systems allow to model extensions using templates [28]. In addition to purely mechanical simulation and calculation of physical properties of the product, modern simulation tools carry out optimisation tasks and electrical simulations.

5.3. IT support for Production Design

The core task in mass production design is planning of the production technologies and logistics. The targeted and coordinated interaction of these two components leads to the production of the desired quantity in the required time and quality at the desired costs. Production technologies generally refer to transforming one intermediate product to the next within the overall process. The logistical component includes the provision of material and information according to the logistics principle. The whole production process is controlled by a PPC system [29]. Therefore production design has the target to develop appropriate manufacturing processes and to create control programs and work plans. To avoid surprises when it comes to production preparation, it is essential to incorporate production design already in the product design stage [30]. IT support for production design, also known as CAM, can be generalised into two types of systems: NC systems, which serve to create control programs for machines and CAPP tools, which serve to plan internal and external logistics, as well as to simulate the production process in a virtual factory.

Especially in the automotive and aerospace industry, IT supported simulation of production processes were quickly anticipated by the industry and used in practice [31]. The term “virtual factory” circumscribes modelling of products, processes and systems within a virtual environment. The factory and production planning comprises the tasks of plant structure planning, technology planning, process planning, layout planning, material flow, logistics, resource planning and workplace design. These tasks require a number of different models. To enable coherent planning, the models must be interoperable and provide data exchange possibilities. In practice this often leads to problems. An important part of a virtual factory is the visualisation of the production process. With the help of 3D models in virtual production, problem sources are recognised, understood and eliminated before production ramp-up [32].

5.4. IT support for Product Development Management

Product Development Management Software tools support at least one of the three management targets: quality, cost or time and can thus be classified accordingly.

To cope with the demand for consistent documentation of information and application of reliable statistic methods, IT support in Quality Management is increasingly popular. Tasks of such CAQ systems in the field of product development concern administration of quality data and organisation

of testing including result interpretation. Additional functionality is change management, as well as statistical and preventive methods for quality planning, such as quality function deployment and failure mode and effects analysis [33]. Not included in CAQ systems are calculations and simulations, which are functionalities of CAE systems. The role of CAQ systems can therefore be summarised as quality planning, assurance and control [34].

In the area of collecting cost oriented development information, software enables process-oriented development controlling by granting efficient access to process data. While quality management and project management also employ discrete tools, operational development controlling is supported by an ERP-system in almost every bigger company. The advantage of those systems is that data of any business process is recorded uniformly and can be processed directly. This leverages transparency of resource flows within the company and avoids interface problems and media discontinuity among isolated applications [35].

The various kinds of tools that are used for Project Management in practice have one thing in common: they focus on managing time and resources. While especially small businesses content themselves using standard office software such as text processing, shared calendars or email for communication purposes, others use specialised software for single- or multiproject management. A PM tool should offer multiple views to show only functionality to a certain group of users that is really needed. Tailor-made functionality is therefore in the focus of current tools. Additional trends are mobile access to project data and, if not already integrated within, interfaces to ERP-systems [36].

5.5. IT support for Information Management

Any PDP generates information artefacts that are in most cases collected in an integrated product information model. Information management can therefore be considered as the basis for product development, linking various building blocks of the process. It includes all tasks and challenges dealing with management, storage or delivery of product — or project-related information. Therefore the primary tasks include providing information technology infrastructure, mapping product and process data to software systems, integrating and linking development-related software tools, as well as offering team collaboration systems [13, 37]. Because deliverables of modern, virtual development process are exclusively made up of digital documents, also the top management has to perceive data management and cooperation systems as a key element of product development [38].

Knowledge Management is becoming an increasingly important task in product development. Studies have shown that NPD process success positively relies on implementation of organisational learning an knowledge management [39]. The Knowledge Management tool family is numerous and versatile. It reaches from knowledge retrieval tools like Data Mining to extensive Enterprise Information Systems [40]. KMS support search, delivery, visualisation, structuring, linking, acquisition and communication of knowledge. Furthermore, they often include functionality for knowledge administration, data analysis and computer based learning [41]. PDM systems target on administrating all documents, models and the like that are generated during the development process as well as supplying the right process stakeholders with the right data and information [42].

A major trend in NPD is the emergence of development networks that include multiple companies in different countries [43]. Moreover, the expertise from several fields has to be considered at every stage of the design process. The goal of collaborative design is to break barriers between departments and individuals [44]. Traditionally, groupware can be classified in a time-location matrix. One dimension describes whether communication is synchronous or asynchronous, the other indicates whether the team is at the same location [45]. According to Teufel *et al.* [46] the aim of CSCW systems is to support communication, coordination and cooperation. Recently CSCW undergoes an enormous push from the web 2.0 hype [47].

6. DISCUSSION

Since the development of computer-aided design and production started in the early 50 s, much has changed. Computer assistance is no longer just confined to individual areas of product development,

but is enclosing the process and is omnipresent. Today, NPD is not only done by engineers, it is an integrated process carried out by an interdisciplinary team that often works distributed globally. The changes that affect the process are ultimately reflected in the available IT support. The system landscape of product development has become a veritable zoo of support tools and it is often difficult to keep track. The wide range of NPD software is also a result of the time that has elapsed since the key technologies were developed. As technology advances and the software industry matures, consolidation is happening in the market. An example is the market for CAD and CAM software where most small software companies that existed in the pioneer times were absorbed by competitors, so that the market has largely consolidated and is now dominated by few large companies. Although integration of information is a strong trend within the NPD software market, focus is only on integration within the particular engineering domains and there is still a wide gap in terms of cross-domain integration (e.g. eCAD — mCAD) [42]. Another aspect of NPD that has to be addressed in future is the development of services that are offered around the actual product. Since manufactures increasingly generate profits not from the product itself, but from product-service systems (PSS) [48], service engineering will play an important role in future product development [49]. Although there are a few approaches for computer aided service engineering (CASE) and some methodologies for designing a PSS [50], there are still no IT tools specially designed to support the development of an entire PSS.

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