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DESIGN AUTOMATION IN SMEs – CURRENT STATE, POTENTIAL, NEED AND REQUIREMENTS

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Abstract

This paper presents a study on design automation at eleven small and medium enterprises (SMEs). These have been interviewed on their need of, perceived potential for, current state of, requirements and wishes on, design automation as well as their view on realization and implementation of design automation applications. The companies' answers are presented together with an interpreted potential for design automation.

1. Introduction

To ensure and improve the competitiveness of SMEs acting in an environment of distributed engineering and globalization, four important factors are low cost, short lead-time, improved product performance and the possibility to adapt products to different costumer specifications. One way of gaining these competitive advantages is to adopt an approach where products are based on prepared design. If some of the work related to these products and design tasks are automated, the design process can become more effective and efficient. This allows for: shortened lead-time of product designs, cost estimates [1], more optimized product designs and customer tailoring, while giving the designers more time for creative problem solving. Companies have to consider the advantages of design automaton, its realization and implementation as well as its applicability. Other issues of importance are: scope of implementation, how far to push the automation level, procedure for development, identification of information needed, definition of information models [2], strategy and procedure for handling and storing design process information [3], selection of suitable application software [4], initial cost, maintenance cost, and the use of internal and external expertise. To support companies in choosing appropriate type and level of design automation there is a need to address the important questions about potential, wishes, requirements, constraints and actual need of design automation. This paper addresses these questions from a SME standpoint. Other issues addressed are the current state of design automation in industry, and the companies' view on some important aspects and criteria of design automation characteristics, realization and implementation.

2. Framework of design automation

This framework is the basis for a broadened definition of design automation, and is proposed as a means for analyzing and defining companies' potential for implementation of design automation. The potential is evaluated by addressing the company: wishes, requirements, constraints, prerequisites and actual need.

To define a contemporary definition of design automation, a design-for-manufacture approach has to be adopted in contrast to the traditional design process approach (Figure 1).

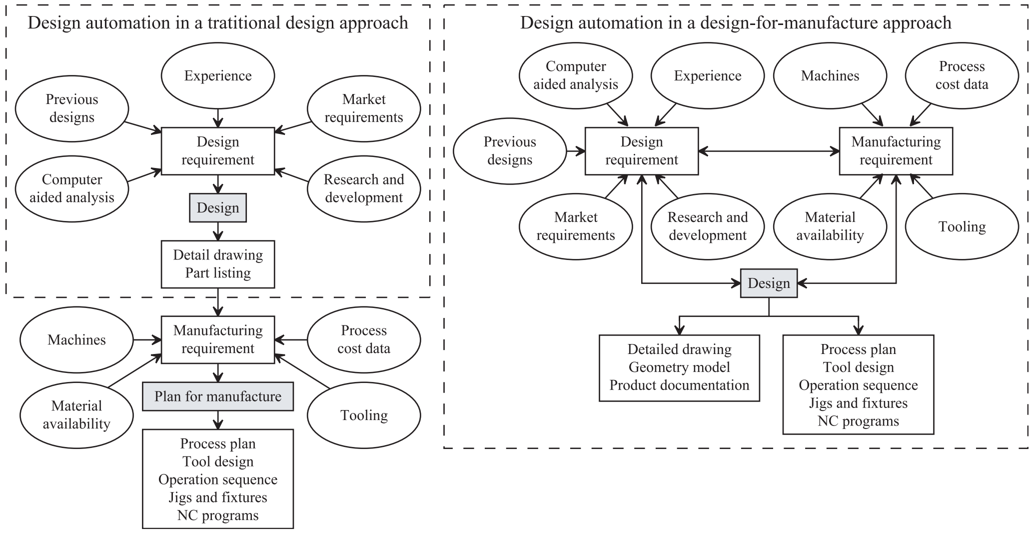

Figure 1. Two different approaches to design, adopted and revised from [5], were the scope of design automation is extended in the design-for-manufacture approach.

Design automation

"Automation is the application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible." [6].

In this work the term *design automation* refer to:

> *Engineering support by implementation of information and knowledge in solutions, tools, or systems, that are pre-planned for reuse and support the progress of the design process. The scope of the definition encompasses computerized automation of tasks that directly or indirectly are related to the design process in the range of individual components to complete products.*

Design automation can be divided into two types: information handling (storage with retrieval and/or forwarding) and knowledge processing. An archiving system for the reuse of CAD-files or a reusable spreadsheet for weight calculation of a prismatic object are examples of the two types in their simplest form. A PDM system incorporating large amounts of knowledge, i.e. thousands of rules and algorithms, for variant design based on different customer specifications combines the two types and is an example of high level of design automation. The aim of design automation is to support one or more of the areas: *design synthesis*, *design analysis*, and *plan for manufacture*, which according to [7] belong to the system-level design and detail design phases. Design synthesis can enclose design analysis and plan for manufacture, using their results for further synthesis in a loop towards refined solutions.

Need of design automation - objectives and motives

Four important general objectives of design automation are to reduce costs, cut lead-time, improve product performance and the possibility to adapt products to different costumer specifications. The overall motive for implementing design automation is to gain an effective and efficient product development process. This is typically done in the areas of: making tasks more efficient and effective, improve working practice, and enhance product characteristics. In a study presented in [4] twelve Swedish companies were asked about their primary motives behind the utilisation of, or interest in design automation in the form of Rule-Based Engineering. The answers where categorized according to Figure 2.

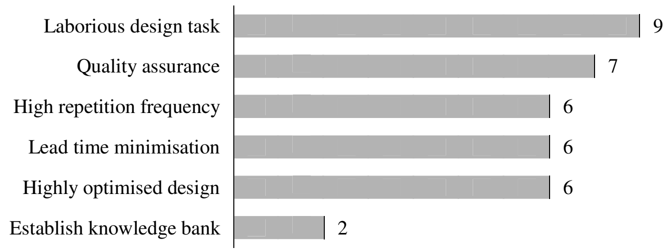

Figure 2. Primary motives for Rule-Based Engineering systems. Sum of answers from 12 companies. [4]

By refinement and expansion of the motives above, an extended number of reasons to address the need of a more effective and efficient design process can be stated as: shorten lead time for delivery, reduce labour intensive tasks, reuse prior case solutions, quality assurance (ensure individual, time, and process independent design solution), reduce repetitive tasks, shorten lead time for quotations, optimize design, enable customer tailoring, manage design/manufacturing requirements and constraints, establish/guarantee a knowledge base, enhance producibility, support process planning, enable cost estimates, and generate documentation.

Product variant and variant design

Redesign of an existing product is a common design task in industry [8] and according to [9] perhaps more than 90% of industrial design activity is based on variant design. In this work, the term *variant design* in design automation refers to solutions for the purpose of managing a number of pre-planned co-existing [10] versions, commonly called variants (implying presented products with differently fixed attributes). The solutions can also be used to manage unplanned versions, called revisions [11].

Customization degree

According to [12] three design customization concepts in the sales delivery process are: *assemble to order*, *engineer to order*, and *custom engineered*. A fourth, more traditional way of meeting customer needs is to present a number of product variants *made to stock*. The range of these variants can be based on company defined values as well as identified customer needs. These concepts for customer tailoring can all be supported by design automation. The concepts are explained below and arranged in levels of increased delivery lead time in the delivery sales process and company ability to meet customer's initial needs and requirements:

- *Select to order* – Catalogue selection were the customer modifies its demands. *Close enough* solution according to the customer's initial needs and requirements.
- *Configure to order* – The company tries, to its best ability, to meet the customers' demands by configuration. *Good enough* solution according to the customer's initial needs and requirements.
- *Engineer to order* – The company meets the customers' demands by original or variant design. *Optimal* solution according to the customer's initial needs and requirements. (In this work including the *custom engineered* concept.)

Design tasks

Tasks, that are repetitive, time-consuming, and/or involve information handling, and which do not involve creative problem solving are suited for automation. An expanded list of design tasks, based on different mechanical design problems as defined in [8], is presented below.

Five tasks (1-5) belong to the system-level design and detail design phases, all with potential for design automation, and one task (6) belongs to the conceptual design phase. All these tasks for mechanical design can be means for customer tailoring where tasks 2-4 are considered variant design tasks. The six design tasks for mechanical design are:

1. *Selection* – Selecting standard components according to given rules.
2. *Parametric design* – Using design tables for variant design.
3. *Parametric design with topology changes* – Using design tables with additional pre-planned changes in topology for variant design (product families).
4. *Configuration / packing* – Using a rule base to combine a set of given components to meet desired product performance.
5. *Redesign* – Adapting, optimizing and improving existing function or products to meet new conditions and demands.
6. *Original design* – Development of a new solution, function or product according to specification of requirements.

A specific product or variant development process can include one or more of the defined tasks to varying extent, all depending on the level of design task formalization. Design of a product variant can, for example, include 100% original design if the knowledge of an added function is new to the involved engineers, or 0% original design if knowledge or experience from an old solution exist, all depending on the level of design task formalization.

<u>Level of design task formalization and process maturity</u>

The Capability Maturity Model (CMM), describing a framework of the: five stages of evolution, levels of capability, and levels of process maturity, has been adapted to describe the levels of maturity within the product development process by [13]. From this description a shortened list of design task and process knowledge formalization is drawn:

1. *Ad-hoc process (initial level)* – The process is event, individual and need driven.
2. *Implicit process (repeatable level)* – The process and its comprised knowledge is not documented, but exist in the minds of the users and consequently followed.
3. *Explicit process (defined level)* – The process and its comprised knowledge is well documented and followed.

The stages are arranged in a natural order of evolution towards the fourth level *implemented process (managed level),* reached when task or process automation is implemented. A fifth level, *optimal process (optimal level)*, can be reached by refining the process.

<u>Potential for design automation</u>

According to [14] the potential for design automation increases with the product maturity, expressed as known rules in relation to all rules in the development process, and higher customization degree, expressed as number of variants in relation to number of deliveries, and can be visualized in a maturity-customization and automation potential diagram. The measure for potential can be expanded to include the design process maturity for the purpose of capturing single tasks, in a specific product design process, suited for design automation.

<u>Scope and format of implementation</u>

The scope of design automation is defined as either a support for, or a complete solution of a single component, a group of components, a single product, or a group of products. There exist a number of means for enhanced computer support and implementation of design automation, for example: CAD-macro, expert system, Case Based Reasoning (CBR) system, configurator (and PDM system), computational template (e.g. spread sheet, application software for technical computing), in-house developed application, coupled application software (e.g. spread sheet linked to CAD system), standalone Knowledge Based Engineering (KBE) system, and CAD system with integrated KBE functions.

Realization, implementation and application characteristics

A method supporting planning, implementation and evaluation of open and user friendly in-house developed design systems has been proposed. This method has been used for implementation and evaluation of a pilot system [15] for variant design automation. The method recommends a modular system approach aimed at fulfilling a number of general criteria of design automation characteristics, first stated in [16] for the purpose of parametric solid model evaluation. These criteria, adapted for the purpose of implemented system evaluation in [15], are in this paper presented in a general context:

- *Transparency* – implying a clear and accessible documentation and visualization of the product and design knowledge used as well as for the implemented control functions (design process).
- *User readable and understandable knowledge* – implying a form of realization where the knowledge can be expressed in a user readable and understandable format.
- *Scalability* – implying a realization architecture that allows the application to grow and expand (be upgraded and further developed) with emerging details, additional or refined tasks to be performed, additional knowledge to be added, and additional application modules to be implemented.
- *Flexibility* – implying a realization architecture that allows the application to grow and expand with additional variants and products.
- *Longevity* – implying a realization that is not dependent on a single specialized vendor and incorporates some level of transparent, as well as user readable and understandable knowledge allowing for easy application overview and maintenance.
- *Ease of use* – implying a realization that is easy to implement, use, and maintain.
- *Level of investment* – implying an initially low cost for implementation.
- *Effort of development* – implying a low effort of developing the application (if done in-hose) and the knowledge base as well as expanding the application and the knowledge base.
- *Integration* – implying a realization architecture that enables sharing of information with other applications.

Other important issues and external factors which can have a substantial impact on the general criteria's level of fulfilment are:

- *Independence* – implying that the user is independent of a single vendor or creator for maintenance, upgrade or support.
- *Help with implementation* – implying total application and knowledge base implementation by the vendor or creator.
- *Access to support* – implying easy access to support (e.g. from a vendor or creator).
- *Access to education* – implying existence of documentation and training courses for implemented application.

3. Study of design automation in SMEs

An interview study was selected to address companies' view on potential, wishes, requirements, constraints, actual need of design automation, and the importance of the general criteria of design automation characteristics as well as the current state of design automation at their company. Some of the questions were intended, by interpretation, to lead to an assessment of potential for design automation. The interview was divided into the six sections: company introduction, need, potential, implementation/realization, current state, and future prospects. Eleven companies were selected for the interview: ten companies situated in a region with a long tradition of manufacturing SMEs and one additional partner company (selected due to prior collaboration in the area of design automation). Companies' representatives were interviewed by two interviewers (one performing the actual interview and one taking notes). The respondents had their main knowledge in the area of design. A interview form with a combination of multiple choice, order of precedence, and open questions was used.

In the following paragraphs companies' answers on some key questions are presented in tables and diagrams showing unaltered data. In some cases these answers are followed by respondent's comments. The eleven companies are from here on denoted A trough K.

3.1. Company introduction

<u>Company background</u>

The respondents had their focus on design and/or production and sales. They ranged from design engineers to company presidents, all with insight on the company status regarding product range, design tasks and processes as well as computer support and design automation. The companies' (or group of companies') turnover ranged from 2-50 million, with companies' export ranging from 10% to 98% of sales with a majority above 60%. The number of employees working with design and development ranged from 3-50. Four of the companies saw themselves as subcontractors, one at system level and three at component level. Nine of the companies saw themselves as product suppliers, three acting on a consumer market, seven acting on a business-to-business market and two acting on a organization (or government) market.

<u>Required product documentation</u>

All companies' representatives answered that there existed some demand of product documentation either by the customers, the company itself or both, and were presented with a list from which they were asked to identify required product documentation (Table 1).

Table 1. Required product documentation of companies A through K and sum thereof.

	A	B	C	D	E	F	G	H	I	J	K	∑
CAD files		√	√		√		√	√		√	√	7
Drawings		√	√	√	√		√	√			√	7
Calculations			√	√	√		√			√	√	6
Analysis	√		√		√		√				√	5
Test results	√	√	√	√	√	√	√	√		√	√	10
Other		√	√	√	√	√	√	√	√	√	√	10

Other examples of documentation added to the list were: manuals, technical documentation, function documentation, general instructions and illustrations, educational and training documentation, assembly documentation, safety certificates, quality documentation, preliminary quotations, time schedules, application software and program printouts, and spare part catalogues.

3.2. Need

Perceived need

All respondents saw a need of a more efficient and effective design process and all but two, who answered that they were not sure, thought that design automation could be a means of achieving this. All but one of the respondents answered that the company had considered implementing some form of computer support.

Need of a more efficient and effective design process

The respondents were asked to choose five reasons they would like to address for the need of a more efficient and effective design process from a refined and expanded list of primary motives behind the utilisation of, or interest in design automation (Figure 3). The respondents did not identify any additional reasons to add to the list.

Figure 3. Reasons to address for the need of a more efficient and effective design process. Sum of answers from companies A through K.

3.3. Potential

Design tasks

The companies' representatives were asked to estimate percentage of time designers spent on different design tasks (methods) associated with generating new products or product variants in a general product development process at their companies (Table 2).

Table 2. Percentage of time dedicated to different tasks. Answers and average from companies A through K given in percentage.

	A	B	C	D	E	F	G	H	I	J	K	Average
Selection	10	20	20				5	20	5	5	5	8.2
Parametric design	10					10	5		5	5	25	5.5
Parametric design with topology changes	10			90	55		5			5	30	17.7
Configuration / packing		30			15	10	10		35	5	20	11.4
Redesign		30	30	10	20	60	65	60	20	30	10	30.5
Original design	70	20	50		10	20	10	20	35	50	10	26.7

Level of design task formalization and process maturity

In addition to the question about time spent on different design tasks the respondents were asked to estimate the percentage of time spent on different design process approaches and type of formalization (Table 3).

Table 3. Percentage of time dedicated to different design process approaches. Answers and average from companies A through K given in percentage.

	A	B	C	D	E	F	G	H	I	J	K	Average
Explicit process	10	0	30	60	50	0	5	50	0	25	60	27.2
Implicit process	0	70	0	0	30	60	80	0	100	50	20	37.3
Ad-hoc process	70	30	70	40	20	40	15	50	0	25	20	35.5

Process maturity and customization degree

The companies' representatives were asked to plot some of their products in a modified maturity-customization and automation potential diagram (Figure 4).

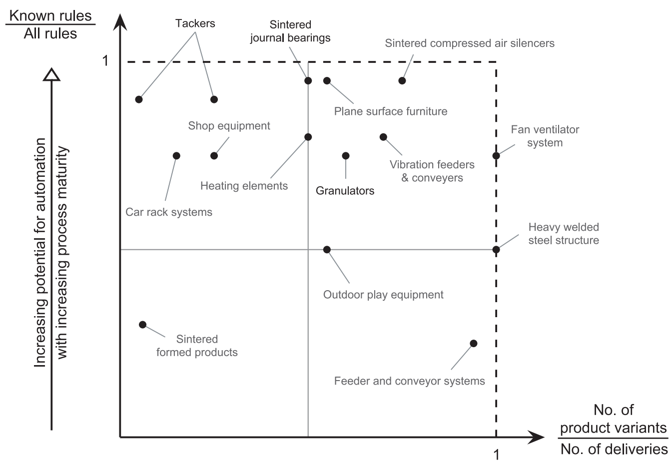

Figure 4. Companies' products plotted in the maturity-customization and automation potential diagram.

Solution strategies

The companies' representatives were asked if they could identify any solution strategies and methods (tools) used in the design process. They were also asked if they continuously structured their solutions (Table 4).

Table 4. Identified solution strategies and methods as well as structuring of solutions. The sum of answers from companies A through K are shown.

	Always	Often	Seldom	Never
Creative methods	2	7	2	-
Literature studies	-	3	7	1
Patent search	1	3	6	1
Competitor analysis	-	6	5	-
Prior cases (own)	9	1	1	-
Use of experts	-	6	5	-
Design handbooks (internal)	-	5	2	4
Design catalogues (external)	-	7	2	2
Solution structuring	1	3	4	3

Other solution added were: trial and error, prototype testing, and discussions with customers.

Identified problems

The companies' representatives were asked if they experienced any problems associated with the design process. They were asked to choose common problems from a predefined list and categorize the experienced problems as occurring or frequent (Table 5).

Table 5. Identified problems associated with the design process. The sum of answers from companies A through K are shown with the individual company's answer categorized as occurring (O) and frequent (F).

	A	B	C	D	E	F	G	H	I	J	K	Occurring	Frequent
Time demanding task	O	F	O	-	F	-	O	F	-	F	F	3	5
Resource demanding tasks	O	F	O	-	F	-	O	F	-	F	F	3	5
Routine tasks	F	F	-	-	F	-	O	F	F	O	O	3	5
Lack of information													
Individual knowledge (experts)	O	F	-	-	O	-	-	F	-	O	-	3	2
Fragmented knowledge (several individuals)	F	F	-	-	O	O	-	O	-	O	F	4	3
Information hard to find		O	-	-	O	O	-	O	F	O	O	6	1
Unsynchronized information flow	O	F	-	O	O	F	-	F	F	-	F	3	5
Iterative process	O	F	F	O	O	-	O	O	-	F	F	5	4
Quality deficiency due to unstructured process	O	O	-	O	O	-	-	O	O	O	O	8	-

Perceived potential

On the question on perceived potential for enhanced computer support or design automation, all but two of the companies' representatives answered that they themselves saw potential. One who did not see a potential said that he was not sure if there was any or not, and one simply stated that there was no potential at the time, but that it would probably be in three years time. One of the respondents who did see potential continued saying that he was unsure of how big the potential was. One respondent who also saw a potential raised some concerns about implementing enhanced computer support by asking the rhetorical question: "Are we big enough."

Use of experts

All but one respondent answered that their company had expert involved in their design processes. Several said that they in fact had more than one and that they saw themselves as being to dependant on individuals or that they did not perceive their staff as versatile enough. Some of the areas of expertise were: project coordination, products, components and subsystems, method development, innovative product development, manufacturing and assembly, tool design, safety issues and regulations, calculations, patent engineering and CAE coordinators.

Tasks for customer tailoring

All but one company representative answered that they in some way tailor designed products for their customers. They were asked how they did this according to a predefined list of design tasks (Figure 5).

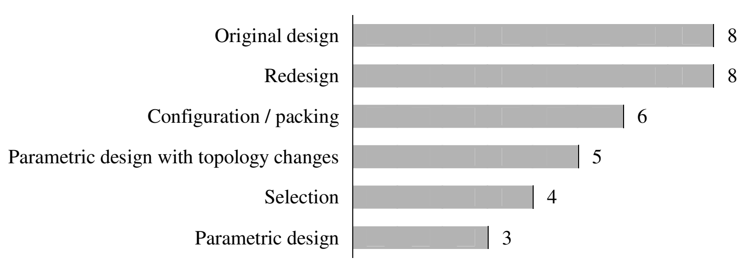

Figure 5. Design activities for custom tailoring. Sum of answers from companies A through K.

Customization degree

The companies' representatives were also asked to choose from a predefined list to what extent they custom tailored their products (Figure 6).

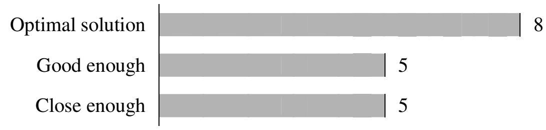

Figure 6. Extent of custom tailoring. Sum of answers from companies A through K.

3.4. Realization/Implementation– requirements, constraints and wishes

General criteria of design automation characteristics

The companies' representatives were presented with a list of general criteria of design automation characteristics and asked to either delete unimportant criteria from the list or place important criteria in order of relative precedence (Figure 7).

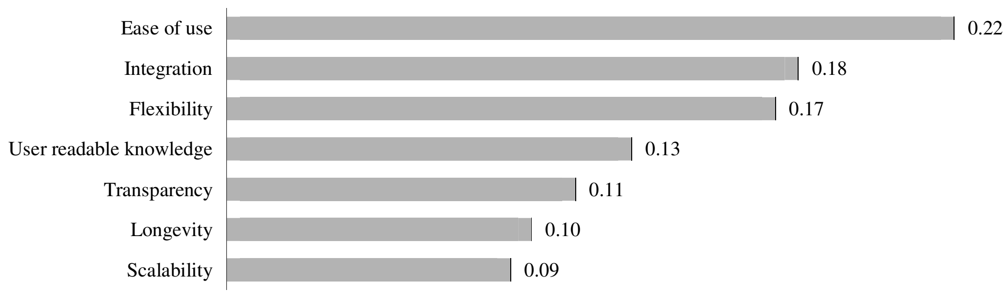

Figure 7. General criteria placed in order of relative precedence. Average comparative weight factor from companies A through K where higher is better.

Ease of use, integration, longevity, and scalability were each deleted as unimportant a total of one time. User readable knowledge, and transparency were each deleted as unimportant a total of two times.

The companies' representatives were then presented with a additional list comprised of important issues and external factors and asked to either delete unimportant criteria from the list or place important criteria in order of relative precedence (Figure 8).

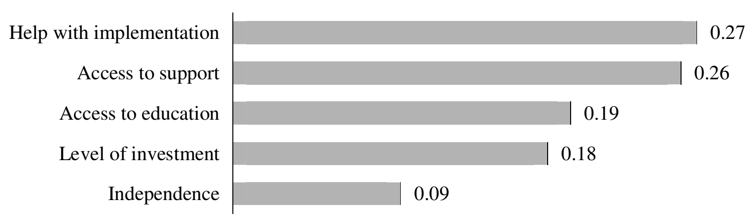

Figure 8. Important issues and external factors placed in order of relative precedence. Average comparative weight factor from companies A through K where higher is better.

Help with implementation, access to education, and level of investment were each deleted as unimportant a total of one time. Independence was deleted as unimportant a total of two times.

Scope of implementation – companies' view

The respondents were asked to what extent computer support or design automation should be implemented to be resource and cost efficient and they answered according to Table 6.

Table 6. Extent of system implementation. Answers from companies A through K.

A	“Always begin with task solution. There is a relation between transparency, black-box and total product solution.”
B	“Total solution. Interactive process support. If possible total automation but it feels somewhat science fiction.”
C	“Task solution for production layouts.”
D	“Task solution systems to begin with, which later are linked together. Total automation.”
E	“Have not yet given the extent of automation any thought. Task solutions for some products. Interactive process support.”
F	“Interactive support. Task solution. I do not think it is possible to aim for total automation.”
G	“Aim towards product solution by implementing task solutions on the way, but I do not believe in total product solutions.”
H	“Task solution. Interactive process support. To totally automate is a matter of cost.”
I	“Task solution to 80% of product design tasks. Process support.”
J	“Task solution. Interactive process support. I do not believe in total automation.”
K	“Task solution and process support to begin with and product solution as an aim.”

3.5. Current state

Format of implementation

The companies’ representatives were asked about what type of computer support that was in use at their companies at the time of the interview (Table 7 & 8).

Table 7. Type of computer supports in use at companies A through K. Computer supports focused on in the interview are marked with an X.

	A	B	C	D	E	F	G	H	I	J	K
CAD macros			√	√	√			√		√	√
Expert systems											
Cased Based Reasoning							X	√			
Configurators				√	√			√			
Computational templates		X	X	√			√	√	X	X	√
Coupled applications				√	√		√	X	√	√	X
Stand-alone KBE systems											
CAD integrated KBE											
In-house developed systems				X	X		√	√			

Table 8. Focused computer support (marked by X in Table 7).

	Systems focused on in interview
B	Computational template - Preliminary cost calculation spread sheet
C	Computational template - Quotation calculation sheet
D	In-house developed system - Product preparation
E	In-house developed system - Lisp-program linked to CAD for heating element layout
G	Cased Based Reasoning - Selection of prior solutions for prototype testing and variant development (pilot system)
H	Coupled applications - ERP connected to CAD
I	Computational template - Calculation spread sheet for packaging design
J	Computational template - Design automation of ropeway for play system by calculation spread sheet
K	Coupled applications – Design automation of subsystem variants (pilot system)

Scope of implementation

The companies’ representatives were asked about the scope of their implemented computer support (Table 9).

Table 9. The scope of implemented design automation.

	Single component	Group of components	Single product	Group of products
Support	1	3	-	-
Complete	2	1	2	1

Reasons for implementation

The companies’ representatives were asked about the reasons for implementing their computer support (Table 10).

Table 10. Reasons for implementation of computer support.

	B	C	D	E	G	H	I	J	K
Reduce labour intensive tasks			√		√	√		√	√
Reuse of prior case solutions		√		√	√	√		√	
Ensure individual, time, and process independent design solution				√	√			√	
Reduce repetitive tasks				√	√	√			√
Shorten lead time for quotations	√	√							
Shorten lead time for delivery					√	√			√
Manage design/manufacturing requirements and constraints						√			
Optimize design					√			√	
Establish / guarantee a knowledge base					√				
Enhance producibility					√	√			√
Support process planning			√	√		√			√
Enable cost estimates	√	√							√
Enable customer tailoring			√		√				√
Generate documentation					√	√		√	
Other							√		

The respondent from company I stated that they did not have any particular reason form implementing their computer support other than the specific functions were enabled “as a bonus” with implementation of their CAD system.

Why selected realization/implementation

The companies’ representatives were asked about the reasons for the selection of realization/ implementation format (Table 11).

Table 11. Systems focused on in interview. Systems from companies A through K.

	Why the selected realization/implementation
B	“Quick and easy implementation in a application software that everyone else is using.”
C	“We already had and knew the application software, but a database approach might have been better.”
D	“The designer should be able to work in a familiar environment - CAD, not programming code”
E	“Technology available at the time of implementation.”
G	“Research project where the opportunity was presented.”
H	“Other companies used the application software for the same problems on an international scale.”
I	“Bonus with implementation of their CAD system.”
J	“Because it was simple to accomplish and Excel is easy to use.”
K	“The need grew in a natural process. It was a conscious derision as we saw the opportunities.”

3.6. Future prospects

Planned future implementation and targeted areas

Five of the eleven companies answered that they planned an implementation of enhanced computer support for the purpose of design automation. Three of the companies had thought about implementation but had no current planes. Some of the areas planned to address were, automated: product design, variant design, FEM, cost estimates, cost calculations, documentation, and sales support.

Design automation as a competitive means

Ten of the eleven companies saw design automation as a competitive means and several of the respondents mentioned shortened lead-time as the most important factor. One mentioned that: “If the company had not automated the design process to its present level we would not still have production here (in Sweden).” Another said: “It is important to reduce design cost as it is becoming more difficult to get the asking price for a product.”

4. Summary and interpretation

Current state, need, and requirements

There is a varying state of design automation at the eleven interviewed SMEs to date. One has the design knowledge fully integrated and coded in in-house developed design systems where orders are automatically processed with generation of machine code for manufacture and BOM-lists for assembly. Some have systems where applications are linked together, while other companies use CAD macros or spreadsheets for specific design tasks. No applications were based on either expert or KBE systems. The scope of implemented design automation comprises both support for, and total solution of, design tasks within the design process of single and groups of individual components or complete products.

Need of a more efficient and effective design process were expressed in areas of: shorten lead-time for delivery, reduce labour intensive tasks, reuse of prior case solutions, quality assurance, reduce repetitive tasks, and shorten lead-time for quotations. All but two, thought that design automation could be a means of achieving a more efficient and effective design process

Of the general criteria of design automation characteristics, ease of use, integration, and flexibility, were rated highest. Scalability was rated the lowest. Issues and external factors perceived as most important were help with implementation and access to support. Independence was rated the lowest. One respondent mentioned the requirement of system accessibility, adding that the system must not be perceived as an additional work load, and if not easy to use no one will use it. Another respondent stressed that it is important that the process is transparent and that connection to (integration with) other application software can sometimes make a system too complex, rendering it hard to work with. One respondent stressed that a system built in the wrong way harms transparency, readability and ease of use, and that there is a risk of losing the core competence if knowledge becomes hidden. The more complex a system gets the more knowledge about the system is needed (by the user) and there is a risk of loosing some degrees of freedom, the opportunity of being creative as well as the grip on reality. Also there is the risk of the company becoming dependent on some individuals.

A common view among the interviewed companies was that design automation realization and implementation should start with task(s) solution(s) as an interactive process support. Some expressed that the aim should be towards total automation while others thought it to be unrealistic. One said that a system intended to fully automate a design process is too complex a task and not cost-benefit balanced. Concerns were raised on design systems ending up as “isolated islands” or black boxes with the tasks and processes carried out by the system implemented in a way that is not readable and understandable to the end user.

Interpreted potential

There is an interpreted potential for design automation based on:

- Demand of different product documentations, where automation can support the generating of documentation.
- Expressed need of a more efficient and effective design process in areas were potential for design automation exists.
- Large amount of variant design tasks suited for automation.
- Explicit design processes which, if suited for automation, simplifies the realization of design automation.

- Relative high technology levels (product and process complexity) and high maturity of processes suited for automation (and explicit processes).
- Solution strategies with potential for automation, e.g. use of prior cases and internal design handbooks.
- Identified problems within the design processes in areas that can be supported by automation.
- Customer tailoring by design tasks suited for automation.

The interpretation of potential can be further supported by a comprehensive view on interrelated companies' statements:

The stated high share of original design tasks (27%) in new product or product variant design may seem confusing in respect to the companies' businesses and products. This could be explained by high process maturity but still low level of explicit task formalization. In combination with expressed problems concerning information accessibility, this leads to an unstructured process from an individual designers' point of view, and gives rise to unnecessary original designs. If a designer never has seen a design solution (despite its actual existence) he/she has to invent (re-invent) it.

If the extent of explicit task and process formalization had been higher, the potential for design automation had also been higher. Working with formalization of design tasks and processes increases the potential for design automation, while working with design automation consequently leads to a more formalized structure of design tasks and processes. Where to begin is a question of high relevance for companies that consider design automation.

5. Conclusion

There is a varying state of design automation in the interviewed SMEs. The companies see a need of design automation and express great interest in the subject. They also prefer to work with design automation in a step-by-steps approach, beginning with task support. The design processes tend to be unstructured and design automation can serve as an incentive to structure the tasks and processes.

The overall conclusion based on the interviews and discussions with the companies' representatives is that there is potential for design automation in varying areas of the design process and that there is a need of a general framework, methods and tools, supporting realization of design automation. As an example there is a need of general criteria for design automation, supporting the choice of the right strategy for, and format of, design automation realization and implementation. Some criteria are presented in this paper together with their relative importance addressed from a SME point of view.

References

[1] Elgh F., Sunnersjö S., "An automated cost estimating system for variant design based on the method of successive calculus", Proceedings of ICED 03: International Conference on Engineering Design, August 19-21, 2003, Stockholm, Sweden.

[2] Elgh, F., "A generic framework for automated cost evaluation of product variants and fabrication plants", Proceedings of DETC2004: ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September 28 - October 2, 2004, Salt Lake City, Utah.

[3] Cederfeldt, M., “Variant design automation - Strategy and procedure for storing design process information”, Proceedings of DETC2004: ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September 28 - October 2, 2004, Salt Lake City, Utah.

[4] Amen R., Rask R. and Sunnersjö S., “Matching design tasks to knowledge-based software tools – When intuition does not suffice”, Proceedings of DETC99: ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September 12-15, 1999, Las Vegas, Nevada.

[5] Hannam, R. G., “Computer integrated manufacturing: from concepts to realization”, Addison-Wesley, Harlow, 1997.

[6] Encyclopædia Britannica Inc., “Britannica Online”, [http://www.eb.com], (acc. 2005-03-14), Encyclopædia Britannica Inc., 2004.

[7] Ulrich, K.T., Eppinger, S. D., “Product Design and Development”, McGraw-Hill Inc., New York, 1995.

[8] Ullman, D.G., “The Mechanical Design Process”, McGraw-Hill Inc., New York, 1997.

[9] Encanação, J.L., Lindner, R., Schlechtendahl, E.G., “Computer Aided Design – Fundamentals and System Architectures”, Springer-Verlag, Berlin, 1990.

[10] Casanova Paez, M., Van Der Straeten, R. and Jonckers V., “Supporting Evolution in Component-based Development using Component Libraries”, Proceedings of CSRM2003: European Conference on Software Maintenance and Reengineering, pp. 123-132, March 26-28, 2003, Benevento, Italy.

[11] Whitgift, D., “Methods and Tools for Software Configuration Management”, John Wiley & Sons Ltd., West Sussex, 1991.

[12] Mesihovic, S., Malmqvist, J., “PDM System Support for the Sales-Delivery Process of Engineer-to-Order Products”, Proceedings of Produktmodeller 2000: Conference on Product Modelling, November 7-8, 2000, Linköping, Sweden.

[13] Crow, K., “Capability Maturity Model”, [http://www.npd-solutions.com], (acc. 2005-03-14), DRM Associates, 2004.

[14] Sunnersjö, S., “AID-Features: A New Tool for Design Automation”, Proceedings of CACD’94: Lancaster International Workshop on Engineering Design, J. Sharp et al., eds., Lancaster University Engineering Design Centre, Lancaster, pp. 241-258, 1994.

[15] Elgh F., Cederfeldt M., “A Design Automated System Supporting Design for Cost – Underlying Method of Development, System Applicability and User Experiences”, Accepted for presentation and publication at CE2005: ISPE International Conference on Concurrent Engineering, July 25-26, 2005, Dallas, Texas.

[16] Cederfeldt, M., Sunnersjö, S., “Solid Modelling with Dimensional and Topological Variability”, Proceedings of ICED 03: International Conference on Engineering Design, August 19-21, 2003, Stockholm, Sweden.

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