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INDUSTRIAL RELEVANCE OF DESIGN SCIENCE – AN EMPIRICAL STUDY

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1. Introduction

As a field in which researchers aim to improve products, processes and tools in product development, design science is closely intertwined with industry. In fact, industrial relevance and utility serve as motivation for the majority of conference papers, journal articles, and dissertations. That is why industrial relevance is the very raison d'être for design science. Throughout its comparatively short history, industrial relevance of design science has been vigorously debated. [Hubka and Eder 1996] conclude that "the way into engineering practice has not yet been found". According to [Blessing 2002], the lack of use of results in practice is a major issue that needs to be addressed urgently. [Sheldon 2005], however, states that many outputs from design science are "being adopted by industry with considerable delight and satisfaction".

In this contribution, we intend to establish an empirical foundation on the question of industrial relevance of design science in Switzerland. We executed ten interviews with CTOs and development leaders from nine Swiss manufacturing companies for that purpose. The selection of companies roughly represents the industrial structure of Switzerland with the number of employees ranging from about 200 to about 40,000. The industries covered are machine industry (four companies), supplying industry (three companies), and medical engineering (two companies). The product lines of the companies interviewed primarily comprise make-to-order and assemble-to-order products [Rudberg and Wikner 2004]. Each interview lasted about one hour and was executed based on an eight-sided questionnaire.

For the purpose of this paper, we define the industrial relevance of design science as comprising the following aspects.

- *Level of recognition*: How is design science perceived in industry and what is expected by industrial leaders?
- *Knowledge transfer*: Are results from research used in industry?
- *Topics*: How important are the topics covered in design science to industrial leaders?

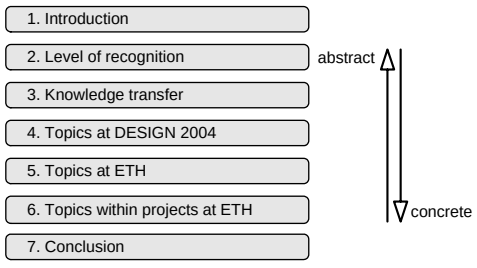

Figure 1. Structure of paper

In order to answer these questions, this paper is structured into the sections shown in Figure 1. In Section 2, we address the level of recognition of design science in industry. The extent to which knowledge is transferred between academia and industry is discussed in Section 3. The industrial importance of current topics in design science is discussed in the following three sections. We start by assessing the topics at DESIGN 2004 and gradually get more concrete by addressing current projects in design science at ETH Zurich and concrete topics within these projects.

2. Level of recognition

In this section, we assess the level of recognition and the importance attributed to design science.

Do you have a clear idea of the research done in design science?

Only three out of ten interviewees consider themselves as having a clear idea about the research done in design science (Figure 2). One of the interviewees had not even heard about research in this field before. Two influences seem to determine the degree of familiarity with design science. First, the larger the corporation, the more the interviewees are familiar with design science. Second, design science seems to be more widely known in mature, cost-driven businesses than in young, technology-driven businesses.

How do you assess the importance of design science (e.g., compared to production engineering or materials science?

The relative importance of design science is generally perceived to be similar to slightly smaller than neighboring fields (Figure 2). Many respondents, however, state that design science could potentially be of much higher importance to them if they had a clearer idea about the research performed in this field. Besides, several respondents judge design science to be more comprehensive than other fields. One respondent attributes very high importance to design science as it deals with soft, yet important knowledge generally not considered in engineering research .

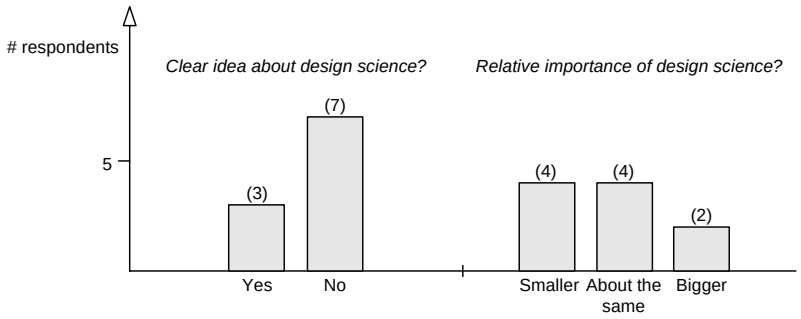

Figure 2. Clear idea about design science and comparative importance

3. Knowledge transfer

In this section, we assess the degree and type of knowledge transfer as well as industrial expectations.

Do you perceive a knowledge transfer between academia and industry in design science?

Half of the interviewees perceive no knowledge transfer at all between industry and academia. Of those respondents who notice a knowledge transfer, all are involved in research projects in design science with academia (Figure 3). There is also some knowledge transfer through personal contacts with academic researchers and university graduates. Knowledge transfer through conferences, conference publications, books and journals is negligible. An additional medium for knowledge transfer not captured in the questionnaire but brought up by interviewees are university spin-offs in design science.

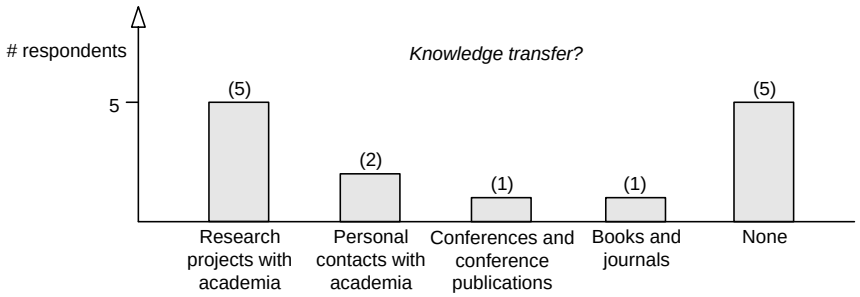

Figure 3. Knowledge transfer between academia and industry

How are your experiences in research projects with academia in design science and other fields?

About half of the respondents views past research projects as fulfilling or exceeding expectations. Another half responds that past research projects with academia partly fulfilled expectations. The number of respondents stating that projects failed to meet expectations is negligible. Interestingly, research projects in design science and research projects in other fields do not score differently.

4. Topics at DESIGN 2004

In this section, we address the different streams of the DESIGN 2004 conference to get a feedback on the different fields in design science. In detail, we mention the headings of the conference proceeding and ask our interviewees to rank the importance of the keywords according to the following categories:

- Not of industrial relevance (0 points)
- Of industrial relevance (1 point)
- Relevant in the product development of the own company (includes industrial relevance)
- (2 points)

All streams are judged as being industrially relevant by at least 70% of respondents (Figure).

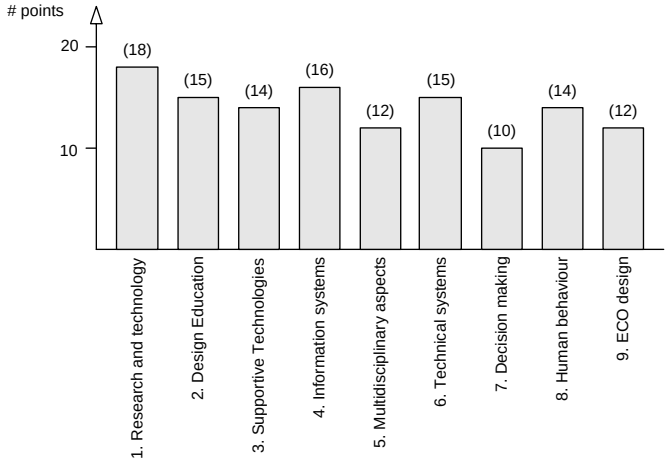

Figure 4. Knowledge transfer between academia and industry

This is a strong commitment to the topics of design science in general. In order to clarify this impression based on concrete research activities in design science, we use the current projects in design science at ETH Zurich. The results are summarized in the following section.

5. Topics at ETH

The Center of Product Design of the ETH Zurich is working in close cooperation with industrial partners of the manufacturing industry. Every research project has at least one industrial partner. The concept of our research center is based on research activities to improve the product, the related processes and the information technology applied. The existing product strategy and a multinational product development environment are considered as well. Research projects are carried out by one or several Ph.D. students with at least one of them dedicating 100% of her/his work to the research topics of the project.

One of the key objectives within our empirical study is to identify the topics that are industrially relevant to the Swiss manufacturing industry. To answer this question, we introduce the current projects at our research center and try to find out which of them are judged to be of industrial relevance. There are twelve projects that are presented by their title and a short description. Obviously, we cannot present the entire project and its results due to the lack of time in the interviews.

All projects are judged as being industrially relevant by at least 50% of our interview partners (Figure). To be more exact, four of the projects are interesting for half of the interviewees. The others are interesting for even more. The comparatively interesting projects address virtual reality as a solution for the cooperation of global design teams, the improvement of the innovation process, the development of mechatronic products or the improvement of the communication and flow of information in the product design process.

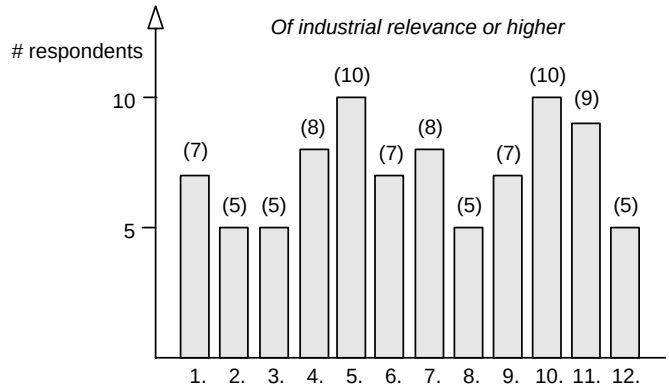

Figure 5. Industrial relevance of ETH projects

Two of the projects are interesting for all interview partners. As a surprise, both of them address the early stages of the product design process. The first consists of elaborating support for the fuzzy front end, the other is a method for product structuring in the early phases. Our interpretation of this result is that all companies have to deal with the fuzzy front end and the key to answering the increasing need for innovation is in the early phases of the innovation process. Finally, there is a general interest for conceptional projects with strategic objectives.

6. Topics within projects at ETH

Since it is not possible to discuss all of the projects outlined in the last section in detail, we now address the following specific topics in the fields of products, processes, and tools in detail. These three fields are in the center of our research and we assume that any research in design science should circle around these fields. We relate the responses from industry to current and past research efforts in the field of the respective question. Based on this comparison, we place the topic into one of the following categories and give a short explanation.

- Covered in research, implemented in industry
- Covered in research, not implemented in industry
- Not sufficiently covered in research

6.1 Product

The field of product structuring, most notably product platforms and modular product families, has been among the most vividly discussed topics in design science in recent years [Gershenson at el. 2003]. Several current projects at ETH deal with product structuring. That is why we assess the extent to which academic efforts in product structuring match with industrial needs.

Do you apply methods of product structuring?

Since the companies interviewed primarily manufacture make-to-order and assemble-to-order products, it is not surprising that nearly all apply product families to reuse resources across several single products. All but two companies apply modularization and all but three companies product platforms. It is important to note though that the concepts of modularization and above all of product platforms are only coarsely defined in most companies. Most of the interviewees are not able to give a clear definition of their product platform nor of modularity. In most cases, definitions circle around the description of potential benefits such as reuse of components and interface management. Product platforms and product families very often seem to imply the same thing, namely a range of related products. In most companies, product platforms and families do not come from a deliberate process of platform/family definition, but are the result of a product portfolio that evolved over the years.

→ Covered in research, not implemented in industry: The amount of literature on product structuring in the literature is vast. There is a huge number of publications that support the definition of modular product families and product platforms. We observe, however, that none of the methods provided in these publications has found its way to industrial application at our interview partners.

How do you rate the utility of your product structuring in your company?

Two thirds of the respondents estimate the benefit of product structuring in their company to be great and another third estimates it to be average (figure 6). It is surprising that although there is no deliberate, clear product structuring concept, the utility of product structuring is generally considered to be very significant. The product structuring concepts are also quite durable. In more than three quarters of the companies interviewed, they survive seven or more years.

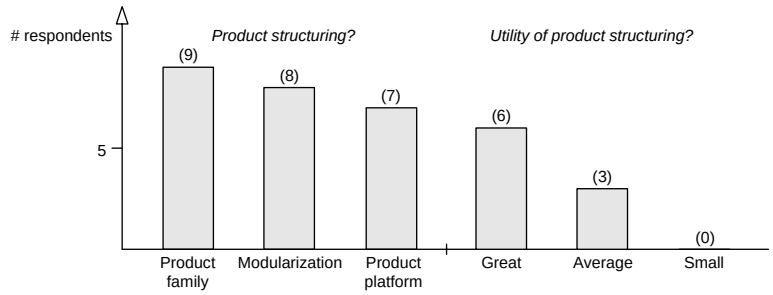

Figure 6. Methods and utility of product structuring

→ Not sufficiently covered in research: There are numerous qualitative statements on the advantages and disadvantages of product structuring in the design science literature [Ulrich and Tung 1991]. An approach to quantify the utility of product structuring in a company has not been realized yet. Still, some efforts in this direction can be observed [Kristjansson and Hildre 2004].

What are your current challenges related to product structuring?

Two primary challenges are identified in the course of the interviews. Five interviewees respond they need support in initially setting up a product structuring concept. Six interviewees face challenges in maintaining their product structuring concept in the market phase in view of changing technologies and customer demands. Six respondents wish a more structured approach to the variant management of product families and platforms for that purpose. This approach should contain above all a

documentation scheme for the product family/platform, tools for maintaining interfaces and key figures for decision-support.
→ Not sufficiently covered in research: The initial definition of a product structuring concept has been extensively treated in the literature [Gershenson at el. 2003]. The variant management of a product platform or family in the market phase, which is judged to be at least as important by respondents, has been left out. More research effort is required here to easily document the product structure, maintain interfaces, and to provide key figures for decision-support.

6.2 Process

As mentioned before, we try to answer some fundamental questions with respect to the product development process. These questions and the results with some statements of the interview partners are presented in the following.

How is the product development process defined and performed in your company?

The product development process is well-defined and carried out according to the process description in the large majority of companies. Seven interview partners state though that deviations from the process description occur in practice. This is due to the fact that the static process descriptions cannot capture the highly dynamic project work. One interview partner states that the deviations from the process description are desired and the project leaders are encouraged to find the easiest way to project success.
→ Covered in research, implemented in industry: The product development process is covered in many publications. Standardization efforts (e.g., ISO 9001) ensure that virtually all companies have a defined product development process.

Is the customer integrated into your product development process?

The customer is a part of the product development process in all companies except one. This implies that either some customers are involved as a reference or all customers are an integrated part of the process. The work with the customer has potential for improvement in two thirds of the companies. One of our interview partners states that the work with the customer could not be better as it has the nature of a frank and critical discussion.
→ Covered in research, not implemented in industry: Intercorporate collaboration in product development is one of the main topics of research in design science. So far, the results gained by these efforts have not yet arrived in industry.

Is the supplier integrated into your product development process?

The supplier is integrated with nearly the same degree as the customer. This underlines the expectation and experience that product development is performed as an intercorporate process. The questions concerning the quality of collaboration with the supplier are answered differently. There are three statements that the collaboration with the supplier is of very good quality. The other interview partners see potential for improvements or even problems in the daily work. As a result, the capability of the supplier is judged to be on a range from low to high level. The main statement expressed by all interviewees is that only a supplier with a high capability in the area of product development is chosen as a potential supplier in building up the supply chain. A new supplier is initially validated by all companies. However, there is a lack of supplier qualification.
→ Covered in research, not implemented in industry: Intercorporate collaboration in product development is one of the main research topics in design science. Still, the majority of research deals with companies on the same level of the supply chain. The specific needs of suppliers are not sufficiently covered.

How are improvement processes carried out in your product development?

We cannot draw a clear conclusion from the answers to this question. There are four interview partners with a strategic concept that is planned for many years. In seven companies, a defined

improvement process is used for strategic measures only. In three companies, improvements are carried out on an ad hoc basis.
→ Not sufficiently covered in research: Change management is covered by research in management disciplines [Hiatt and Creasey 2003]. There is much less literature on change management to be found in design science.

Do you know the capability of your product development?

Seven interview partners are convinced that they are aware of the capability of their product development in all detail or at least have a good impression of their capability. Only two interview partners have to agree that they are not able to assess their product development with respect to their competitors.
→ Covered in research, not implemented in industry: Assessments for performance measurement have been covered in many research projects. A practical use in industry cannot be observed.

6.3 Tools

We shortly address the topic of tools that are used to support the product development process.

What kind of tools do you have and which functions of your PLM-system do you use?

All interview partners have a CAD-system and an ERP-system. Eight out of ten have a system in the context of PLM. Only four have IT in the area of computer supported cooperative work.
All companies with a PLM-system use the functions product data management, release management and change management. Seven use document and product structure management as well. None uses the PLM-system to support project management. Some have other IT-solutions or no IT support for this purpose. Surprisingly, MS Excel is still in use for many applications.
→ Covered in research, implemented in industry: The basic systems for the coordination of the flow of information are well-know in industry and supported by IT-companies.

7. Conclusion

It is clear that no final conclusion on the status of design science can be made on the basis of ten interviews. Still, extensive face-to-face interviews with CTOs and development leaders within the clearly defined Swiss manufacturing industry have been carried out. We are therefore convinced that this empirical basis can be legitimately used to assess the state of design science in Switzerland with respect to the three aspects described in the introduction.
The result of our endeavor to identify the *level of recognition* is that there is no clear idea about design science in industry. We therefore conclude that a lot of work needs to be done by our research center and the design community in general to spread the knowledge about the existence and objectives of design science. We suggest using projects that cover real life problems of industrial partners with the objective of rapidly gaining comprehensible results and a higher participation of industrial leaders at conferences as a way to improve the level of recognition. In doing so, we can build on the asset that design science is judged as having the same or even higher importance than other research disciplines.
The *knowledge transfer* at the moment is established in applied research projects with industry. Other flows of knowledge are not detectable. The knowledge created in academia is not used in industry due to lack of time and difficult access to information. Additional impediments to knowledge transfer are different objectives in industry and academia, especially with respect to the length of projects and the distribution of knowledge.
The *topics* that are covered in design science are persistently interesting to industrial leaders. This applies to the streams of the DESIGN conference as well as the projects carried out at ETH. There are open questions relating to the mode of cooperation between academia and industry and the funding of research projects. A high amount of administrative work and the long duration of research projects further reduce industrial willingness to participate.
Finally, we want to provide some avenues for future research based on industrial needs. First of all, requirements management starting with the identification of customer requirements and continuiting

with their handling throughout the entire product life cycle seems to be a major challenge in today's industrial product development. Second, intercorporate product development is becoming relevant for more and more companies. The identification and improvement of the product development capabilities of a potential supplier are not sufficiently covered in research. Third, a method to carry out variant management of a product family or platform in its market phase is of vital imporatance to industry. Fourth, static process descriptions are no longer capable of capturing the dynamics of product development projects. Finding a solution to this problem is one of the outstanding wishes in industry. Last but not least, the early stages of the product development process need to be addressed more thoroughly due to their large impact in creating innovative solutions and securing a competitive advantage.

Acknowledgement

This paper is dedicated in memoriam of Prof. Dr. Markus Meier. Markus Meier was Professor of Mechanical Engineering, head of the Center for Product Design and a member of the Department of Mechanical and Process Engineering at the Swiss Federal Institute of Technology Zurich from 1996 to 2005.

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