Design Methodology in the Context of the Eindhoven University of Technology "Technology and Society Program"

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1. STRUCTURE OF THE PAPER

In this paper we will first describe the general nature of our research activities, as they are related to the context in which we work (section 2 and 3). Next we will deal with the content of our research and the approach we have developed (sections 4, 5 and 6). Finally the disciplines that are represented in our group, and thereby the body of knowledge from which we seek inspiration, will be discussed (section 7). A list of publications is added to these sections.

2. SOCIALLY ORIENTED DESIGN RESEARCH

In general two types of design methodological research can be distinguished:

1 research that came forth from the practical needs of designers to get more structure into their design activities;

2 research that studies the broader context in which design activities take place (influence of the company's policy, developments in the market, in lawgiving).

One could phrase these two types as the two 'cultures in design methodology' [De Vries, 1993]. Thereby one should realise that here the use of C.P. Snow's terminology only refers to the idea of two separate groups of researchers, each with their own approach, jargon, methods, and not to his distinction between literary and natural scientists.

The first approach—the first to use the term 'design methodology'— resulted in the search for step models that would guide the designer in his/her activities. These models are based on reflection on practice and not on the application of logic (as in the second approach). Generally speaking these models are based on two assumptions:

1 such models can be developed in a technology independant way;

2 design processes follow the order 'analysis - synthesis - evaluation'.

The first assumption becomes evident from the fact that all 'classic' design method handbooks do not use any specific technological context to describe these models. The second assumption can be restated in other terms, like 'determining the list of requirements - concept and detail design - comparison with requirements'. Observation of what real design processes look like have raised doubts about the validity of both assumptions. In the first place design processes are not all alike, but differ from product to product. In the second place analysis, synthesis and evaluation do not necessarily take place in that order, but rather pervade the whole process.

The second approach, which is primarily taken by philosophers, historians, and sociologists (often under the heading of 'technology dynamics'), at first sight may look less practical than the first. This, however, is a false impression. One of the most serious problems modern business corporation are faced with is the need to tune the products to social requirements and constraints. More and more 'the voice of the customer' is looked for. More and more product development is influenced by political influences (this becomes clear in the case of e.g. High Definition TeleVision or the rapidly emerging many new environmental laws). The integration of technical possibilities and social requirements and constraints is the main focus of the second approach in design methodology. The research that is described in this paper must be located in this second approach. Our main aim is to get more insight into the way designs can be developed in such a way that they fit better with the situation in society, in other words what we look for is 'socially oriented design'.

3. THE ROLE OF DESIGN RESEARCH IN THE "TECHNOLOGY AND SOCIETY" PROGRAMME

The faculty of 'Philosophy and Social Sciences' since 1984 has a M.Sc. program entitled "Technology and Society". Internationally such programs are known as 'STS' programs (Science, Technology, Society). In particular in the USA several universities have STS programs (e.g. Penn State, Virginia Tech, Stanford, MIT, Rensselaer). But there are also European institutes with STS programs operating already (e.g. in Manchester, UK and Linköping, Sweden) or in preparation (in some Eastern European countries). These programs are either

1 social science oriented with a special focus on technology, or
2 engineering oriented with a special focus on social and human factors.

The Eindhoven University of Technology (EUT) STS program leads to the title of 'engineer' and therefore is of the second type.

In this program our design methodology activities take place and this to a certain extent determines the content of our research. The general aim of the program is to educate people for doing studies that can support decision making in technological developments. In terms of design this means decision making with respect to the directions into which the design and development of a product or group of products should be guided. In practice this can be the task of a product manager in a large company or the management team of a small company. Usually the results of our studies are not directly useable by designers. Therefore our research belongs to the 'second culture' in design methodology, as described under section 2.

4. DESIGN RESEARCH AND THE NEED TO DISTINGUISH TYPES OF TECHNOLOGIES

The 'STS' nature of our research has been elaborated in the following way:

- by analysing the S-T relationship of the S-T-S complex we identify the need to distinguish three types of technologies when studying the way designs are developed: experience based technologies, macrotechnologies and microtechnologies,
- next we look at the T-S relationship of the S-T-S complex to find out how social factors play a different role in the different types of technologies we have distinguished,
- finally we offer an approach for design strategies that integrates S, T and S: the so-called STeMPJE approach. STeMPJE is the acronym for the initials of the main factors that are included in the approach: Scientific, Technological, Market, Political, Juridical and (A)Esthetical factors.

The three types of technologies can be described as follows:

1 the scientific knowledge that is involved in experience based technologies has been derived from engineering practice rather directly. One could characterise this knowledge as 'tabelised experience'. Because this knowledge is so practical and concrete its use in design mostly is not so complicated (e.g. looking up the relevant table of material properties and reading the necessary data). At the same time, the various bits and pieces of knowledge all deal with very specific phenomena. Hence the difference with:

2 macrotechnologies, where the scientific laws and concepts involved are (i) the result of a mathemetical deduction from basic equations and (ii) concerned with a much broader range of phenomena. This means that the designer has to bridge a gap between the idealised theory and the practice that deals with reality in all its complexity. Sometimes the engineer tries to realise the ideal situation, in other cases he deliberately uses the disturbing factors to reach his goal. Newton's mechanics is a good example of such scientific knowledge. The role of scientific knowledge in macrotechnology is that of accelerating the development of a technology. An example: steam engines already before (classical) thermodynamics was developed and this theory helped improving the steam engines, which proces would probably have taken much more time without scientific knowledge of the behaviour of steam in the machine.

3 In microtechnologies the scientific theories that are involved become even more abstract, as they deal with microscopic structures we can not see. Even when we think we can imagine their nature (regard electrons as little balls) the theory disturbs this picture (electrons are solutions of wave function equations). The development of such theories mostly precedes their application in design. This application is difficult because of the very abstract nature of these theories and therefore often analogies with macro-situations are looked for when designing. At the same time, microtechnologies would never have been developed without such theories. An example: television would still be in its (Nipkov disc) infancy without fundamental knowledge about electrons.

The distinction between these levels is relevant for the development of products, because of the preliminary closure of a certain level at a certain stage of the development (e.g. in the design of microprocessors one does not any more question the microtechnological basis behind the design, but one takes it for granted).

5. THE STEMPJE APPROACH

So far our studies into the development of several technical devices have given us the strong impression that the role of social factors in design differs between the three types of technologies.

In the development of the Brabantia corkscrew we see that scientific knowledge only plays a marginal role. It is the experience of the designer that determines the use of material and shape properties. From the beginning of the development market factors are present and play a vital role.

Almost the opposite is the case in the development of the transistor in the Bell Labs. Here we see a strong emphasis on the use of solid state physics in the beginning of the development, that is certainly not driven by a concrete market, and only later on the product was further elaborated to fit into a certain market. Practical experience with diode and triode tubes rather hampered the process than helped it. In the development of the Plumbicon (a television camera pickup tube, that has been developed by Philips) we see the same essential role of solid state physics: the crucial step from its predecessor (the RCA Vidicon) to the Plumbicon could be taken thanks to intensive research into photoconducting and semiconducting properties of materials.

The case of the Stirling hot air engine shows an example of a macro-technology as a kind of intermediate type of technology: Robert Stirling invented this machine before Carnot wrote his 'Reflexions', but the use of thermodynamics, theories about heat transfer and friction in gas flows helped Philips to improve both power and efficiency substantially in just a few years. During all developments market considerations played a role, in particular price, safety and efficiency.

Knowing these differences is useful for contemporary business corporations when considering their design strategies. When the product to be developed is likely to be a microtechnology, it seems best to choose a microtechnological development approach. Neglecting this can cause serious barriers in the design process, as has been shown in the case of liquid crystal displays (LCD's) with Flat Panel Displays (a daughter corporation of Philips). Only in a very late stage of the development the Philips Research Lab was involved to study the behaviour of the crystals in the display, which helped solve the problem of rubbing the glass, which with the designers had been struggling in an experience based way for a long time already.

Several students have been guided by us when making STeMPJE analyses for business corporations. Some examples of this are:

- ISDN based telephone equipment. A small company in the southern part of the Netherlands wondered what the consequences of the introduction of ISDN (Integrated Digital Network Services) for the development of their telephone equipment would be. A student in the context of his M.Sc. thesis analyses the various STeMPJE factors: the state-of-the-art in ISDN and IC's for digital telephone equipment, the response of customers to the new possibilities of ISDN based services like call-in line identification, the expected emergence of Dutch and European norms for ISDN, and legal issues with respect to privacy of phone calls. Based on this analysis he delivered a set of requirements for the new telephone equipment;

- in a similar way another M.Sc. student made a STeMPJE analysis with respect to the new possibilities for Stirling cycle based refrigerating equipment: the technical state-of-the-art in Stirling engine and cooling machine design, the market sectors and their requirements in terms of temperature range and power, the expected development of national and international laws for stopping all CFC production, and political (financial) support for the development of alternative cooling machines. With this analysis as a basis the student came up with a strategy for developing Stirling cooling machines.

6. TOOLS FOR DESIGN DECISION MAKING

In the context of the 'first culture' in design methodology (see section 2), a number of practical design tools have been developed. Usually these tools take the shape of seemingly easy-to-use prescriptions for activities in the design process. The validity and reliability of the outcomes of such tools seldom are studied. As long as the tools seem to work, there is no worry about what is seen as typically academic questions that have no practical relevance to the designer.

In the 'second culture' though, the philosopical-methodological basis for such tools is studied. Insight into the nature of the tools, the (often hidden) assumptions for their use, and the nature of the outcomes often leads to certain 'caveats' in their application.

An example of such a tool, that caught our interest, is Quality Function Deployment. As this is a tool that pretends to enable a conversion of customers' wishes into engineering features of the product, it fits quite well in our research field, that focuses on technology-society relationships. The current literature merely describes the procedure of QFD as a practical tool. No distinction is made between different types of technology, which, as we have seen before, is more or less typical for the 'first culture' in design methodology.

The procedure for QFD is the following: first the customer's needs (the rows) have to be identified, with priorities that can determine weight factors, next the main features of the product have to be stated (the columns), then the correlations between the customer's needs and the technical features are put into the cells of the matrix, usually in the form of symbols representing weak or strong relationships, then a benchmarking of the company's own product and its competitors is carried out and added to the matrix, and finally technical target values for the relevant features are set. The 'House of Quality' as this matrix is often phrased, is completed by the 'roof': the mutual relationships between the technical features (in fact here the conflicts between different design requirements can be found).

From a methodological point of view this procedure raises several questions, like:

- how is the customer identified: it is the user, or the buyer, or the yet another relevant person,
- what is the nature of the so-called correlations in the cells of the matrix,
- how are they determined
- what type of scale is used for these correlations,
- how is the reliability of these correlations established,
- can the method be applied irrespective of the technology that is involved?

The answers to such questions may lead to guidelines for the prerequisites for the use of QFD as well as for the status that is given to the outcomes in the further design process.

The broader context of QFD is the total quality management idea. Quality should be assured throughout the process of designing, producing and using products (and services). For designers the message is to consider all phases of the product life cycle when designing the product. In practice this leads to terms like: design for production, design for assembly (DFA), failure mode and effect analysis (FMEA), design for maintainance.

A parallel trend in design is: ecodesign or design for sustainability. Here too the whole life cycle of a product has to be taken into account. A tool for this way of designing is: Life Cycle Analysis (LCA). Such analyses prevent a too narrow focus on one phase (e.g. non-degradability after disposal) while forgetting another (e.g. low energy production process). Ecodesign and its tools are studied in our group from the perspective of the STeMPJE approach: how can designs be made successful by integrating knowledge of materials and production processes, desired functions, perception of 'greenness' of the product with the customer, environmental government policy and laws, appearence of the product.

7. DISCIPLINES REPRESENTED IN OUR GROUP

Before describing the disciplines from which we draw, it is neccessary to come back to the nature of our design methodology activities.

The broadest context for studying the nature of technology and design is the philosophy of technology. When this philosophy becomes more empirical and/or more exact through the application of logic, we speak about the methodology of technology and design. Because of the relationships between science and technology, our study of design methodology also makes use of knowledge from natural sciences and the philosophy and methodology of science. As design methodology is part of the curriculum of our STS program, the didactics of technology and design to a modest extent functions as a background for our teaching.

Now the composition of our group can be understood to be appropriate for our field of research:

- prof.dr. Andries Sarlemijn studied philosophy and logic, and specialised in the historical relationships between science and technology and in the philosphy of design,
- dr.ir. Peter A. Kroes studied technical physics, specialised in the philosphy of sciences and took a special interest in the philosophy of technology,
- dr. Marc J. de Vries studied physics, specialised in studying the practical ways in which designs are developed in industries, and has a particular interest in the didactics of technology.

8. PUBLICATIONS

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