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THEORY OF TECHNICAL SYSTEMS (TTS) – ITS ROLE FOR DESIGN THEORY AND METHODOLOGY AND CHALLENGES IN THE FUTURE

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1 Introduction

Considerations on the nature of artefacts (technical products or systems) have always been part of Design Theory and Methodology. If formalised in a scientific manner – as has been described in [Hubka 1973], [Hubka & Eder 1992], [Hubka & Eder 1996] and [Eder & Hosnedl 2008] – we speak of a comprehensive “Theory of Technical Systems” (TTS).
In this context it is quite interesting to investigate the role of artefact concepts or theories in different approaches to Design Theory and Methodology: Quite amazingly, in some of the even well known approaches, TTS is only considered implicitly or even not mentioned at all.
On the other hand, the last couple of years have brought big changes in industrially relevant products and systems, e.g. with regard to their complexity, “multi-disciplinarity” (mechatronic products, Product/Service Systems) and variability.
Moreover, in the field of computer support for design processes (CAx) a big discussion about product models and product modelling is ongoing which is entirely separate from TTS.
Against this background, this contribution shall try to

– investigate the role of TTS in (different approaches to) Design Theory and Methodology
– and reason about challenges of TTS in the future.

Before going into details it should be noted that the general term “systems theory” is very broad indeed:

> “Systems theory is an interdisciplinary field of science. It studies the nature of complex systems in nature, society, and science. More specifically, it is a framework by which one can analyse and/or describe any group of objects that work in concert to produce some result.” [Wikipedia]

Depending on the point of view and the purpose of the respective approach, it has a lot of different derivatives – [Wikipedia] lists almost 50 different types of systems theory. Some aspects relevant and often quoted in engineering are general/philosophical [Stachowiak 1973], decomposition- and behaviour-related (“systems engineering”), dynamics- and control-related (“cybernetics”, “physical systems theory”, [Wellstead 1979]), communication-related, etc.
General knowledge derived from these studies is incorporated in practically all approaches in the field of Design Theory and Methodology, e.g. how to draw borders in order to delimit a (technical) system against its environment, how to define input/output relations across system borders or how to decompose systems hierarchically (all approaches having it on the parts level, many also on more abstract levels such as functional decomposition).
This contribution will not refer to these more general issues which went into TTS, but will rather focus on more specific questions of: What are the elements and relations in different approaches which make them specifically relevant and useful for product development/design?

2 Existing Approaches to TTS

In this section some approaches to TTS in the context of Design Theory and Methodology are briefly presented and commented on. Their selection is, to a certain degree, subjective, but tries to capture well-known and/or related concepts. Time and space permitting, more approaches could and should be studied, e.g. Andreasen's Theory of Domains [Andreasen 1980] (which is, however covered in another contribution to the AEDS 2008 workshop), Gero's so-called Function-Behaviour-Structure Theory (FBS) [Gero 1009], [Gero & Kannengiesser 2004] or the Concept-Knowledge Theory (C-K) of [Hatchuel & Weil 2003]. Additionally, a deeper study of existing concepts for data structures CAx-systems would be interesting, but, for reasons of time and space, could just not be accommodated in this contribution.

2.1 Hubka/Eder/Hosnedl: Design Science

Hubka was one of the first authors who developed an elaborate, design-related Theory of Technical Systems (TTS), first published in [Hubka 1973]. It is also noteworthy that Hubka's approach to TTS, together with his considerations about design processes [Hubka 1976], became an integral part of Hubka's and Eder's Design Science, [Hubka & Eder 1992], [Hubka & Eder 1996], which led to the most recent concepts published by Eder and Hosnedl [Eder & Hosnedl 2008].

In a much simplified overview, the Design Science of Hubka/Eder/Hosnedl consists of:

– Considerations on the ***objects*** being designed and their properties (i.e. TTS),
– statements and recommendations about the ***process*** of and useful operations in designing (i.e. Design Methodology), and
– a concept of how to structure of design-related ***knowledge***.

This paper shall focus on the TTS part. Again simplified, the core of the Hubka/Eder/Hosnedl approach to TTS has the following constituents[2]:

1. A general transformation process model which serves to define the purpose and tasks of the technical system to be or being designed, fig. 1,
2. a model which refers to the kinds of structures of the technical system as they are successivey established according to the stages of the design process, fig. 2, and
3. a structure of (system) properties which define and describe a technical product or system after it has been designed, fig. 3.

Summary and Conclusion:

The Hubka/Eder/Hosnedl approach to TTS is obviously the most comprehensive in existence; no other approach has all three elements listed above. Additionally, it is well coupled with statements and recommendations for the product development/design process.

That is the reason why it is presented first in this paper and why all other approaches (described in the next sub-sections) will be "measured" against it.

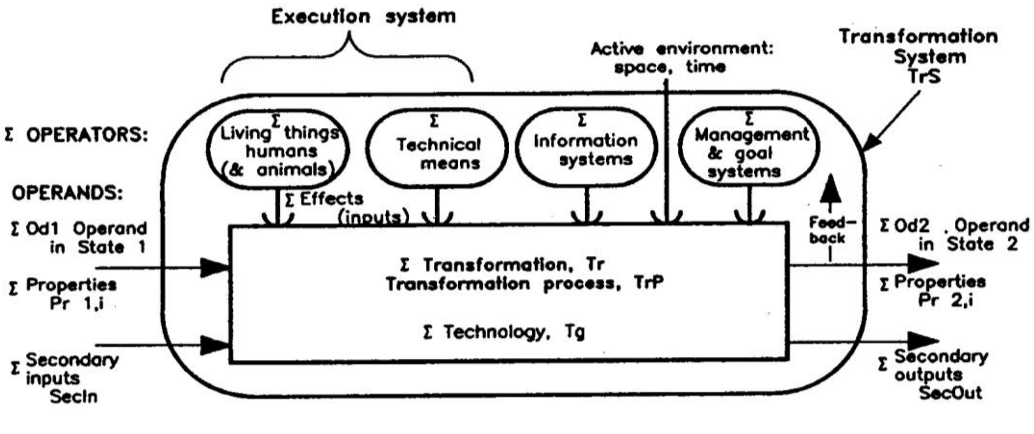


Figure 1: General model of transformation processes [Hubka & Eder 1996]

2 Here: All references and figures taken from [Hubka & Eder 1996] in order to remain consistent.

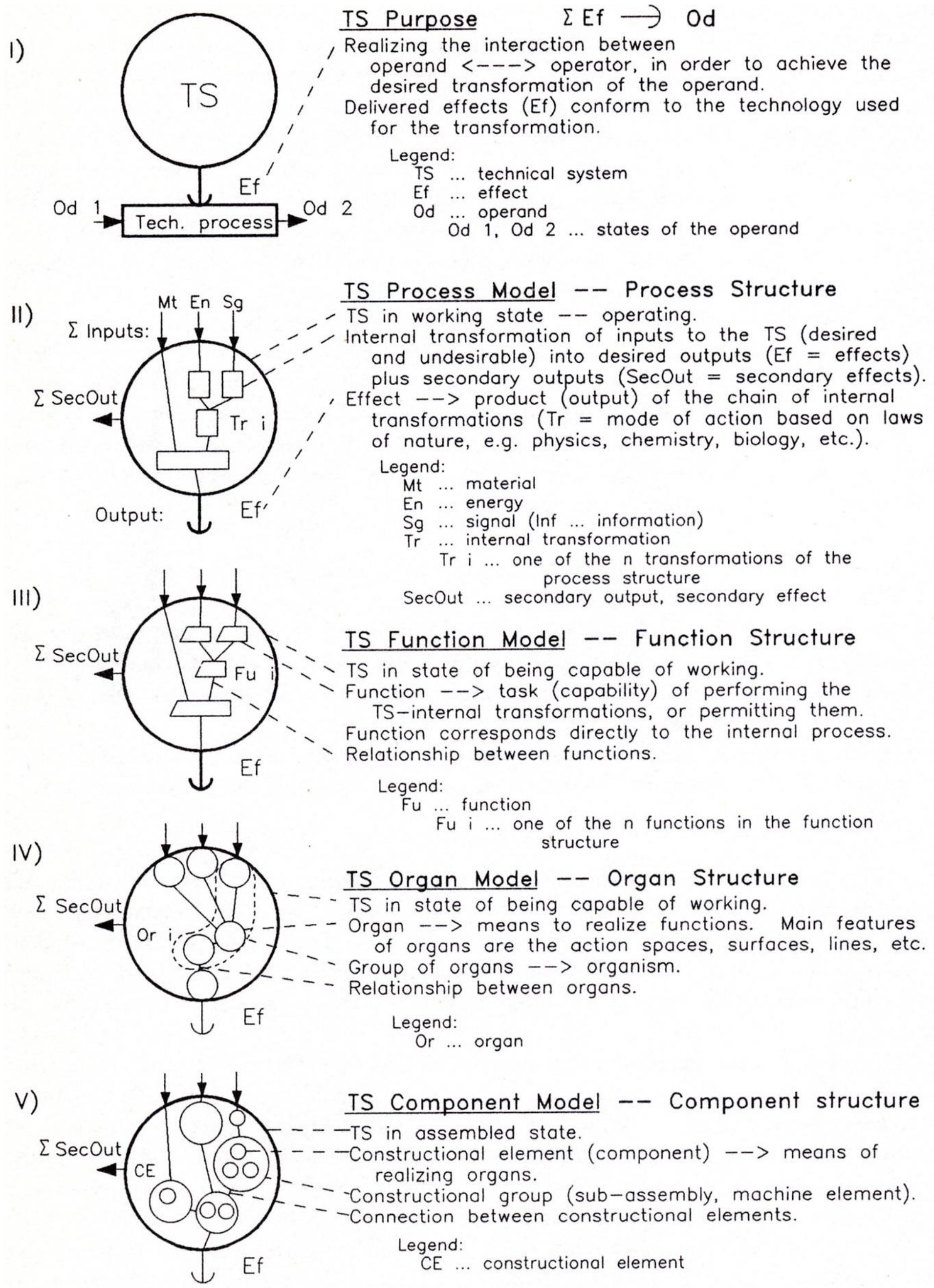


Figure 2: Kinds of structures of the technical system which are successively established during the design process [Hubka & Eder 1996]

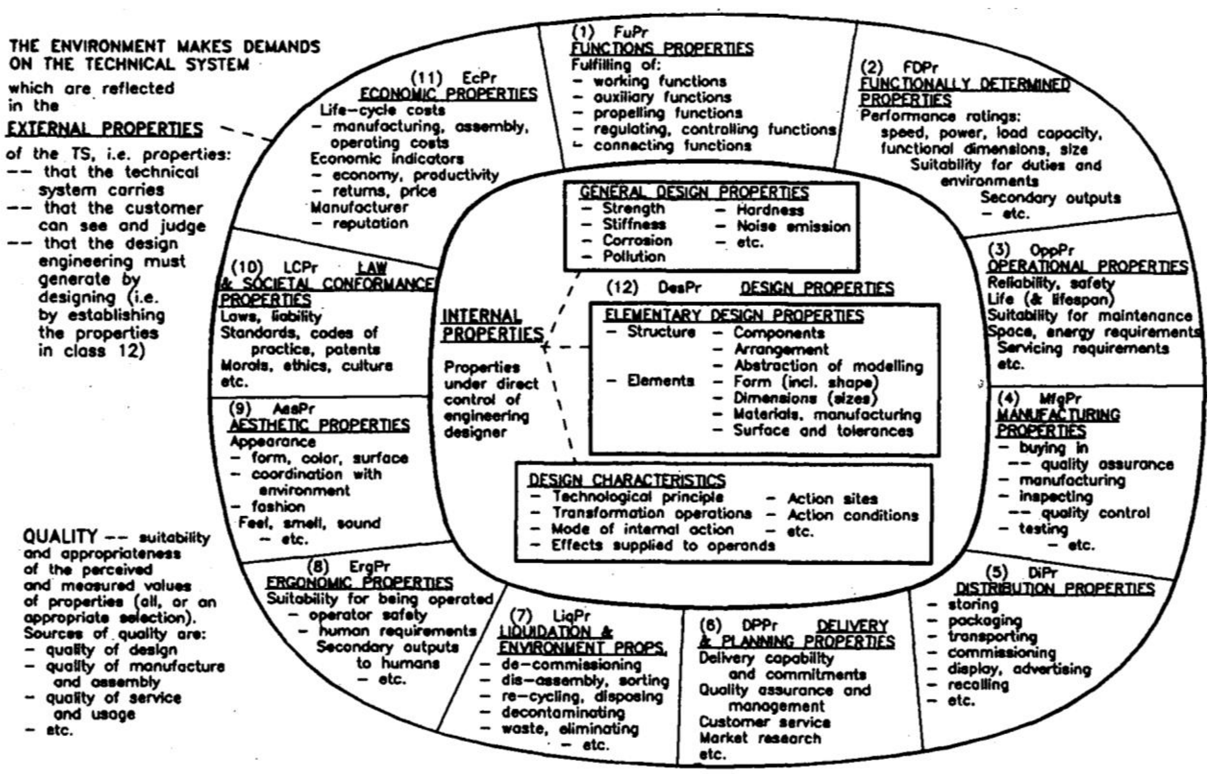


Figure 3: Properties of technical systems [Hubka & Eder 1996]

2.2 East German School: Hansen

Friedrich Hansen can be regarded as one of the most prominent (and also very early) representatives of the former East German school of Design Theory and Methodology. Hansen's first publications on Design Methodology date back to 1953; a first small booklet on "Systematic Design" (as Design Methodology was called at that time, in German: *Konstruktionssystematik*) was published in 1955 [Hansen 1955], this one very much aiming at practice rather than academia. A more comprehensive (and also clearly more science-related) book of the same title was published in 1965 [Hansen 1965].

All these publications covered the design process (i.e. Design Methodology) and had no notion of TTS. This changed in 1974 when Hansen presented his approach to Design Science (in German: *Konstruktionswissenschaft*), [Hansen 1974]. Similar to Hubka and Eder, Hansen's concept of Design Science consists of:

– Considerations on the ***objects*** being designed and their properties (i.e. TTS) and
– statements and recommendations about the ***process*** of and useful operations in designing (i.e. Design Methodology).

Different from Hubka and Eder, it does ***not*** directly cover questions of design-related knowledge.

If we again focus on the TTS part, Hansen's basic approach is strictly "top-down":

A "system" is generally defined as a clearly delimited part of reality which

– has relations to its environment (in German: *Umwelt*, **U**),
– has a structure (**S**) and
– has a function (**F**).

"There is a meaningful relation between these three system properties[3]. Always the function is determined by the structure and depending on the environment." [Hansen 1974]

The properties of a system (vector $\underline{\mathbf{P}}$) can be formally expressed by the following equation:

$$\underline{\mathbf{P}} = \{ \mathbf{U}, \mathbf{F}, \mathbf{S} \} \quad (1)$$

[3] Literal translation, well knowing that the term "property" might be ambiguous in our context.

Based on that, Hansen distinguishes ***technical*** from other systems by defining and describing environments (**U**), structures (**S**) and functions (**F**) specific for them.
Of course, also the interrelationships between **U**, **S** and **F** are studied. Core issue for engineering design are the relations between function and structure, more exactly the ***sets*** of functions and the ***sets*** of structures. These are explained graphically (fig. 4) as well as formally (eq. (2) and (3)). In both representations the double-tipped arrow denotes that the mapping from function to structure is always multivalent while the single-tipped arrow when reasoning from structure to function stands for a univocal relationship.

$$\text{Analysis:} \quad \mathbf{S} \longrightarrow \mathbf{F} \tag{2}$$

$$\text{Synthesis:} \quad \mathbf{F} \twoheadrightarrow \mathbf{S} \tag{3}$$

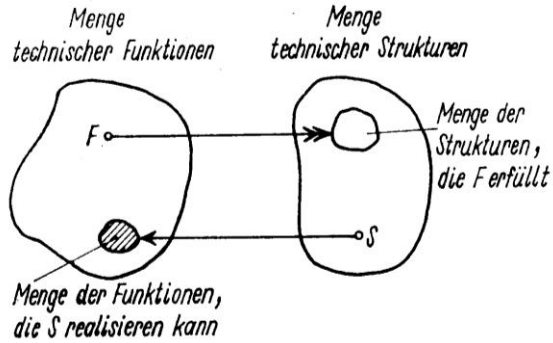


Figure 4:
Relations between function (**F**) and structure (**S**) [Hansen 1974]

Summary and Conclusion:

Hansen's approach to TTS focuses on structuring system properties, i.e. the no. 3 issue of the Hubka/Eder/Hosnedl concept. There is some, but not a very strong relation to Hansen's (earlier!) considerations on the product development/design process (no. 2 issue according to Hubka/Eder/Hosnedl). If read carefully (not covered in this contribution) there is also a concept similar to, but not identical with the transformation process (no. 1 issue) of the Hubka/Eder/Hosnedl approach (called *"Grundprinzip"* of a design).
With hindsight, Hansen's approach to TTS is closely related to much later propositions, e.g. from Suh and Weber (see sub-sections 2.4 and 2.5). It delivers interesting and relevant, for its time even unique contributions to TTS. Seen from today's perspective, however, it remains a little "fuzzy" in some details, even displaying some unsolved overlaps when explaining core terms such as environment, function and structure..

2.3 West German School(s): Pahl/Beitz, Rodenacker, Roth, Koller, VDI-Guidelines

Since the late 1960ies several scientists in West Germany worked in the field of Design Theory and Methodology and published their results in books which have been extremely influential and have seen several editions until this day, e.g. Rodenacker [Rodenacker 1970] to [Rodenacker 1991], Koller [Koller 1976] to [Koller 1998], Pahl and Beitz [Pahl & Beitz 1977] to [Pahl & Beitz 2007a], Roth [Roth 1982], [Roth 1994]. Based on these works and, as far as they were agreed, combining their results, the VDI (Verein Deutscher Ingenieure, (West) German Association of Engineers) brought out a series of guidelines which today consists of [VDI 2221] as the general framework and [VDI 2222.1], [VDI 2223] dedicated to particular phases of the design process.
The book of Pahl and Beitz ([Pahl & Beitz 1983], [Pahl & Beitz 1996], [Pahl & Beitz 2007b]) and the VDI-guideline 2221 [VDI 2221/engl.] are since a long time also available in English, which made these approaches belong to the most widely spread concepts world-wide.
There are differences between the mentioned approaches; but with respect to our topic – basic concepts of TTS – they are not that big. In terms of TTS concepts, the author of this contribution interprets the West German approaches as follows:

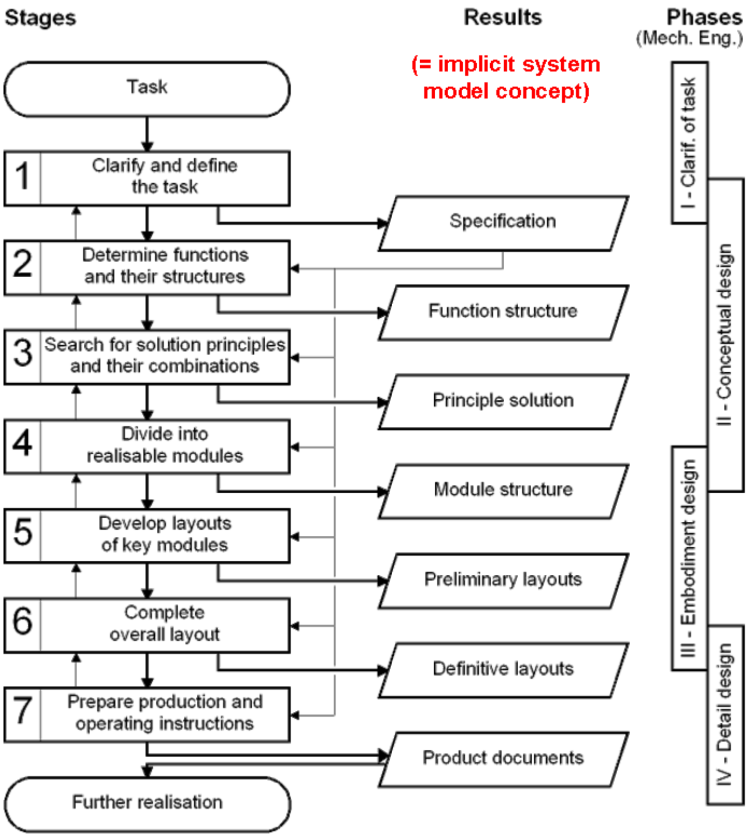
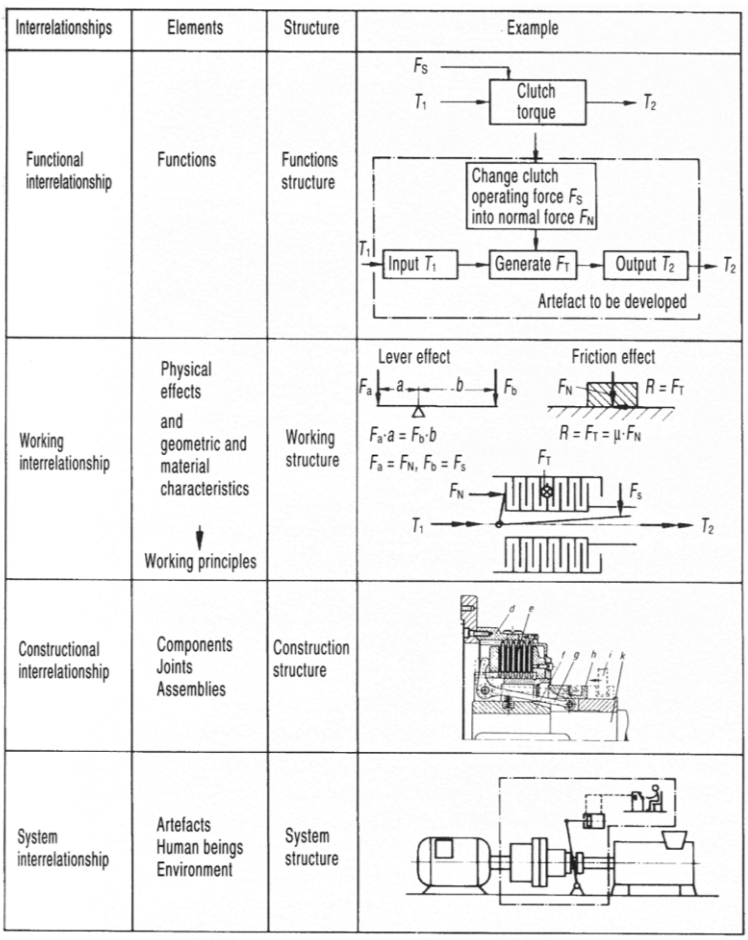


Figure 5:
Implicit concept of modelling technical systems along the (results of the) stages of the design process [VDI 2221]



Interrelationships	Elements	Structure	Example
Functional interrelationship	Functions	Functions structure	
Working interrelationship	Physical effects and geometric and material characteristics → Working principles	Working structure	
Constructional interrelationship	Components Joints Assemblies	Construction structure	
System interrelationship	Artefacts Human beings Environment	System structure	

Figure 6:
Example for the stream of system models and their constituents along the design process [Pahl & Beitz 1996]

– All books have sections on (technical) systems theory which mainly refer to quite general issues (delimitation of systems against their environment, hierarchical decomposition of technical systems).
– With view to contents, all structure their system models along the overall procedure of the design process. Fig. 5 shows this based on [VDI 2221], fig. 6 illustrates the stream of (stage-related) system models (and their decomposition parameters such as element and relation types) by an example taken from [Pahl & Beitz 1996].

Summary and Conclusion:

With regard to TTS, the West German school(s) of Design Theory and Methodology obviously relate(s) to the no. 2 issue of the Hubka/Eder/Hosnedl approach to TTS, i.e. considerations on the contents and constituents of system models defined by the stages of the process (see sub-section 2.1). The no.1 issue (transformation process defining requirements of the technical system) is not addressed, but also not rejected. The no. 3 issue – a general structure of system properties – does not exist.

In this approach the process concept clearly governs the product/system modelling approach: The system concept is justified via the process concept. Or even more pronounced: There exists, in fact, no TTS separate from Design Methodology.

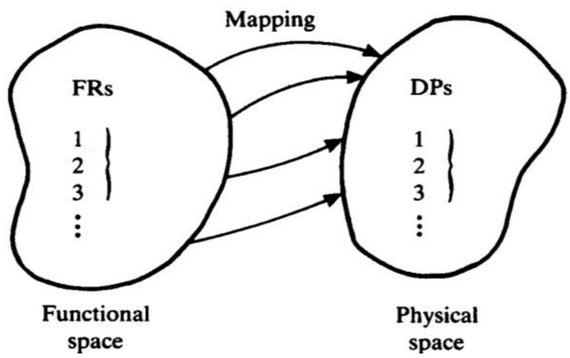
2.4 Suh: Axiomatic Design

N.P. Suh presented an approach to Design Theory and Methodology which is completely different from the “European” concepts described above [Suh 1990], [Suh 2001]. His Theory of “Axiomatic Design” is intensively discussed in the academic as well as the practical world of product development/design, especially in the USA.

The basic concept of Axiomatic Design is that designing is (“just”) seen as a mapping process from the “functional space” into the “physical space”, or, more specifically: mapping a given set of functional requirements (**FR**s, “what we want to achieve”) into a defined set of design parameters (**DP**s, description of “how we want to achieve it”), fig. 7.

This is also clad into a quite elegant mathematical formalisation (mapping between two vectors **FR** and **DP** via the so-called design matrix **A**) which shall not be explained here.

Figure 7:
Design as mapping
functional requirements (**FR**)
to design parameters (**DP**)
[Suh 1990], [Suh 2001]



Based on this concept, Suh formulates two axioms about good designs and develops a number of corollaries and theorems from them in order to support practical development/design processes. The strongest axiom is the independence axiom: “An optimal design always maintains the independence of **FR**s” or “in an acceptable design, the **DP**s and the **FR**s are related in such a way that a specific **DP** can be adjusted to satisfy its corresponding **FR** without affecting other functional requirements”.

Summary and Conclusion:

In the Axiomatic Design approach TTS or product modelling issues are not explicitly addressed – even less so than in the West German school(s) described in the previous sub-section. The collection of known and defined functional requirements (maybe formalised as a vector **FR**), design parameters (**DP**) and relations between the two (**A**) could, however, be seen as an implicit TTS concept.

Interestingly, this is related to the no. 3 issue of the Hubka/Eder/ Hosnedl approach to TTS, i.e. the structure of system properties. Here, no.1 and no. 2 issues (transformation process defining requirements and system models based on design stages, respectively) do not exist. This corresponds with the fact that Axiomatic Design does not have a stage model of the design process; in fact, the "mapping" approach is even openly denying the necessity of having such a model at all.

2.5 Weber: Characteristics/Properties Modelling

Since a couple of years, the author of this contribution develops and propagates an approach called CPM/PDD:

- Characteristics-Properties Modelling (CPM) as the ***product/system*** modelling side and
- based on this, Property-Driven Development (PDD) explaining the ***process*** of developing and designing products.

The approach shall not be explained in detail here, most recent publications – each one stressing different conclusions from the basic approach – are [Weber 2005], [Weber 2007a], [Weber 2007b], [Weber 2008].

The CPM/PDD approach is mainly based on the distinction between characteristics (in German: *Merkmale*) and properties (*Eigenschaften*) of a product[4]:

- The characteristics (formally denoted $\mathbf{C}_i$) describe the structure, shape, dimensions, materials and surfaces of a product (In German: *Struktur und Gestalt*, *Beschaffenheit*). They can be directly influenced or determined by the designer.
- The properties ($\mathbf{P}_j$) describe the product's behaviour (e.g. function, weight, safety and reliability, aesthetic properties, manufacturability, assemblability, environmental friendliness, cost, etc.). They can not be directly influenced by the developer/designer.

The characteristics are very similar to what is called "internal properties" in the Hubka/Eder/ Hosnedl approach to TTS (see sub-section 2.1) and what in Suh's theory of Axiomatic Design (see sub-section 2.4) is called "design parameters". The properties as defined in the CPM/PDD approach are related to the "external properties" of the Hubka/Eder/Hosnedl considerations and to the "functional requirements" according to Suh.

To be able to handle characteristics and properties – literally thousands of them in complex products – and to keep track of them in the development process they have to be structured. Fig. 8 shows the existing propositions, on the left side for the characteristics and on the right side for the properties, respectively.

Additionally, fig. 8 introduces the two main relations between characteristics and properties:

- ***Analysis:*** Based on known/given characteristics of a product its properties are determined (its behaviour is analysed), or – if the product does not yet exist – predicted. Analyses can, in principle, be performed by experiments (using a physical model/mock-up, a prototype or – after manufacturing – the actual product) or "virtually" (by calculation and/or using digital simulation tools).
- ***Synthesis:*** Based on given, i.e. required, set of properties the product's characteristics are established and appropriate values are assigned. Synthesis is the main activity in product development/design: The requirements list is mainly seen as a list of required properties and the task of the designer is to find appropriate solutions, i.e. an appropriate set of characteristics to meet the requirements.

Until now all considerations have been entirely product/system-related (CPM – Characteristics-Properties Modelling of the product/system). Based on this, in the next step a scheme for product development/design processes is presented:

Product development/design is seen as an activity that consists of synthesis-analysis-evaluation cycles and which is controlled by the properties. More exactly: At any time in the process evaluating the "gap" between "Ist"-properties (as-is-properties) and "Soll"-properties (= requirements) drives the process. During the process – in every synthesis step – ever more characteristics of the product are established and their values assigned; in parallel – by

[4] See note on the terminology at the end of this sub-section.

means of the analysis steps – ever more and ever more precise information about the product's properties/behaviour is generated.

In total, the CPM/PDD approach is strongly influenced by the considerations of Hubka/Eder/Hosnedl on properties, but also by Suh's – however implicit – ideas and by experiences from the so-called Feature Technology, i.e. a CAx topic [Weber 1996]. New is:

– The structuring of characteristics and properties is put into the ***centre*** of considerations, not only in terms of product/system modelling (i.e. TTS), but also in terms of process modelling (i.e. methodology).
– There is no a-priori preference among the properties (in the CPM/PDD terminology, i.e. "external properties" according to Hubka/Eder/Hosnedl), all are seen as equal and equally important. Therefore, in the CPM/PDD approach there is no strict stage model of the product development/design process, starting from function and then doing the rest. As stated in [Weber 2007b], [Weber 2008], the question of which properties are relevant and how they are structured as well as the sequence of cycles of the product development/design process entirely depend on the application (e.g. particular branch of Industry and/ or particular company).

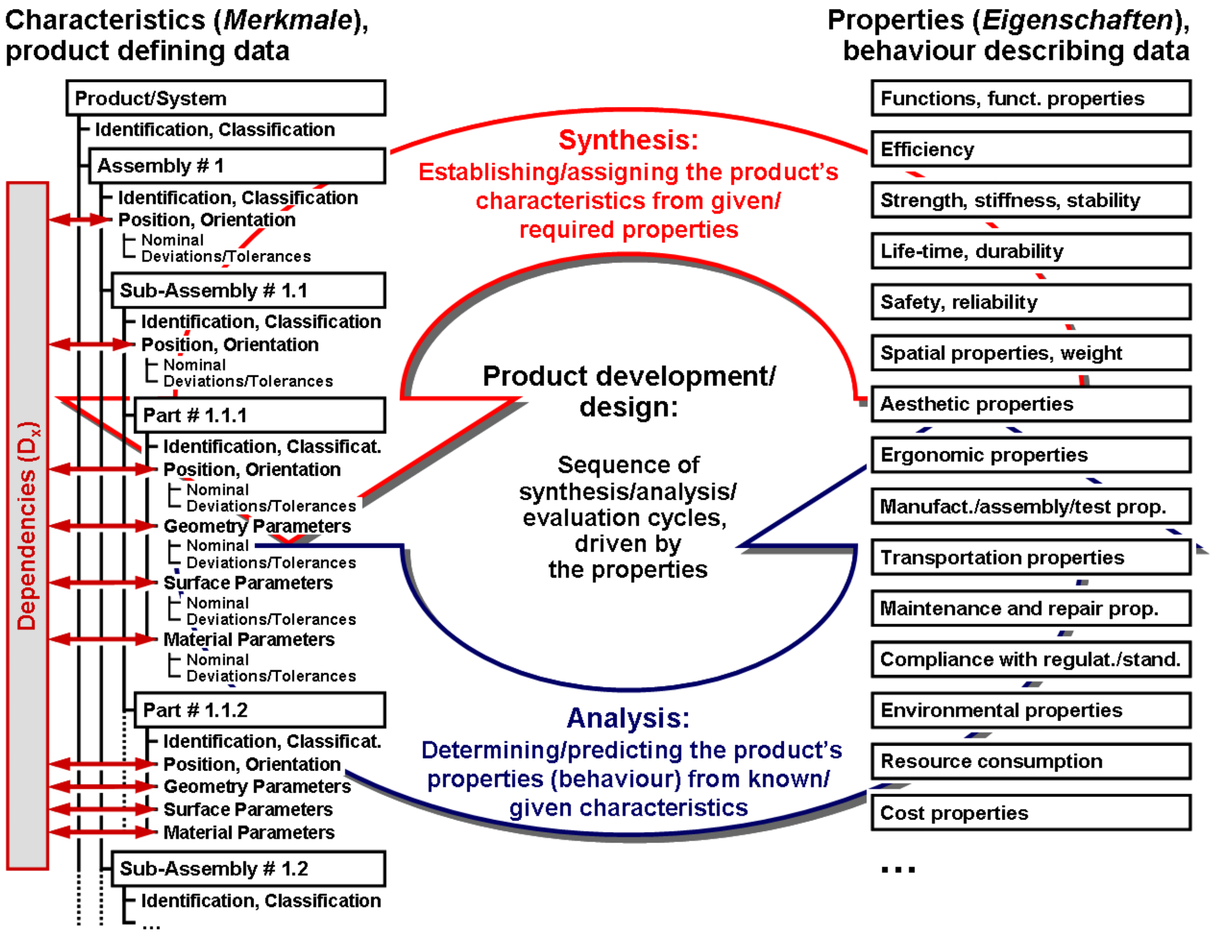


Figure 8: Characteristics-Properties Modelling and Property-Driven Development (CPM/PDD); basic structure of characteristics (left) and properties (right); analysis and synthesis as the two main relations between the two; product development/design as sequence of synthesis/analysis/evaluation cycles, driven by the properties

Summary and Conclusion:

The CPM/PDD concept is clearly related to the no. 3 issue of the Hubka/Eder/Hosnedl approach to TTS, i.e. providing a structure of system properties (or "characteristics" and "properties" in the CPM/PDD terminology). The no.1 issue according to Hubka/Eder/Hosnedl (transformation process defining requirements of the technical system) is not addressed, but (again) also not rejected. The no. 2 issue (considerations on the contents and constituents of system models defined by the stages of the process) can not exist in a general form because all stage models are seen application-specific.

Significant in the CPM/PDD concept is the fact, that modelling the product/system (i.e. TTS) clearly governs the process modelling approach (Design Methodology): Structuring the process is explained via the "characteristics" and "properties" as the main constituents of the product/system model. Or even more pronounced: The TTS approach could be completely separated from the Design Methodology side.

Within CPM/PD this is seen as an advantage, however: In this way it is possible to bring in many other existing process concepts and strategies – even from sources which usually are considered entirely incompatible such as the traditional "European schools" of Design Methodology and Suh's Axiomatic Design. Product/system modelling as the primary entry point of the whole approach also builds strong links to the field of computer-based product models and modelling [Weber 2005].

Note on the terminology of CPM/PDD:

The English terminology "characteristics" and "properties" used in the CPM/PDD approach originally goes back to M.M. Andreasen of the Technical University of Denmark. It has been debated frequently and controversially, not least in the AEDS group and its workshops in Pilsen. The German terms *"Merkmale"* and *"Eigenschaften"* are less of a problem, because they have a certain (nevertheless also not entirely universal) tradition in the German engineering design and machine elements literature.

Despite these debates, for the time being the author of this contribution, at the same time propagator of the CPM/PDD approach, decided to stick to this terminology, because he has big objections against calling all parameters relevant in product development/design "properties" (e.g. "internal and external properties" as in the Hubka/Eder/Hosnedl approach, see sub-section 2.1):

If all relevant parameters are "properties", the clear and for design activities extremely meaningful distinction between what can directly be determined by the designer (what is cause) and what is effected (what is result) starts to become "fuzzy". The situation gets even worse if, instead of two categories of properties (e.g. "internal and external properties" according to the Hubka/Eder/Hosnedl approach), three or more of them are introduced. Even if the structure of all different kinds of properties is scientifically correct, it is very hard to explain and easy to misunderstand for practitioners and students. Therefore, the author prefers a solution where the two main categories (cause and effect in the engineering design sense) are called clearly distinct names and where both sides can be structured individually. The choice of "characteristics" and "properties" serves this intention.

But good advice in the English language and/or open discussions among experts may still lead to even better solutions.

2.6 Product Models and Product Modelling with Computers (Summary)

An area related to TTS is product models and product modelling with computers, i.e. in CAx-systems. Relevant for product development/design are mainly CAD-, CAE- and PDM-systems[5]. It would require an own paper to discuss the present situation and future concepts in this area. Therefore, only some brief remarks on the links between TTS and product modelling will be presented – based on the author's experiences and views.

The discussion on products models/modelling has been led since the 1980ies, necessitated by the ever increasing role of computer support in practically all engineering and business phases (i.e. throughout all product life-phases). Until today the discussion is primarily IT-driven, with data structures, programming paradigms, IT technologies and system architectures as main topics.

[5] CAD – Computer-Aided Design; CAE – Computer-Aided Engineering, used in the sense of calculation and simulation; PDM – Product Data Management.

Because of concentration processes on the side of the IT developers/suppliers during the last years along with "concentration on core competences" strategies on the side of the IT customers/appliers, the development in the whole area is at present strongly dominated by the IT system suppliers rather than application experts. It is also IT-technology-driven rather that application-driven.

In the application field of product development/design[6] much could be improved. The author of this contribution sees the main bottleneck with the fact that CAx-systems for product development/design still have not moved much further than modelling geometry, parts structures and administrating parts-related data (e.g. coupling all information to part numbers). This is not denying the fact that inside the CAx-systems a lot of change has taken place, e.g. evolving from 2D to 3D modelling, adding parametric modelling functionalities, enhancing simulation capabilities both qualitatively and quantitatively, etc.; the basic paradigms, however, have remained fairly static.

While geometry is important and "part-centredness" is extremely useful for some areas (e.g. individual parts sourcing or manufacturing), many issues important for product developers/ designers can not be assessed, let alone supported on this base alone (e.g. function, assembly, safety, maintenance, environmental issues, …).

In the terminology of Weber's CPM/PDD approach this situation could be summarised as being able to capture the characteristics side well (or, in the terminology of Hubka/Eder/Hosnedl, the side of internal properties), but having severe lacks on the side of the properties (or external properties, respectively).

So why are these issues not covered systematically by the IT developers and suppliers? The author of this contribution has the opinion that exactly these issues are extremely difficult to cover ***and*** are quite application-specific, i.e. specific to a particular branch of industry, maybe even to a particular company (see some considerations in [Weber 2007b], [Weber 2008]). Therefore, engagement in this field is hardly paying off for the developers/suppliers.

Another reason may be that – opposed, for instance, to computer science where we encounter a shift of paradigm and new techniques evolving every couple of years – there is no stable concept from science how products ***should*** be modelled – neither in general nor for a specific application context.

This is where – at least for the field of product development/design – Design Theory and Methodology, and in it TTS in particular, could and should come into place: Who else could and should tell the computer experts what to build their software on in terms of contents? However:

- Existing TTS concepts have not really shown any impact on CAx-development. Most intensively tried were (and still are) attempts to derive product model/modelling concepts based on the West German school(s) of Design Theory and Methodology (see subsection 2.3); as these are primarily stressing the no. 2 issue of the Hubka/Eder/Hosnedl approach to TTS, i.e. structuring the contents and constituents of product/system models along the stages of the development/design process, the resulting product models were structured accordingly (in principle similar to the example in fig. 6, but digitised).
- As none of these attempts and proposals were ever taken up and realised beyond a prototype stage, the author of this contribution wonders whether the base might be wrong (at least for computer-based product models/modelling) – maybe we should better start afresh, but based on another TTS concept
- Scientists from the field of Design Theory and Methodology do at present involve themselves even less in product model/modelling discussions than they did in the past [Seifert 1986] – with occasional exceptions, e.g. [Weber 2005]. But how else could our findings gain any influence on these discussions?

[6] Especially in the field of computer support, some authors even prefer to extend from traditional product development/design and integrate it with manufacturing and assembly planning. The result is often denoted with the term "product creation".

3 Conclusions for Future Developments in the Field of TTS

The review of the role of TTS in Design Theory and Methodology described in the previous section brought some interesting insights; the author of this contribution tried to make the main driving forces behind different approaches clear – and was astonished by some of the results himself. Based on these findings, this section attempts to draw conclusions for future developments in the field of TTS. Some of them are phrased as questions rather than recommendations, in particular those with strategic scope.

Of strategic interest to Design Theory and Methodology are the following issues:

1. In Design Theory and Methodology, do we at all need an "own" Theory of Technical Systems (TTS)? Or is the "theory of methodology of designing" the main (and possibly only) goal?
2. If we want an "own" TTS approach, what is its relation to the process side (Design Methodology)? Does TTS govern (at least parts of) design methodology (like in CPM/PDD, sub-section 2.5) or vice versa (like in the West German school(s), sub-section 2.3)? Or semi-detached approaches (like, in principle, the Hubka/Eder/Hosnedl approach, sub-section 2.1, and even more so Hansen's considerations, sub-section 2.2)?

Along with the more strategic questions listed above, the author sees necessities to re-visit and update TTS content-wise – with big challenges. Some (probably not all) issues are:

3. If we decide to invest research effort into TTS, of course a broad discussion on the terminology is required (see e.g. [Birkhofer 2006]). This would definitely be not easy (because you can not "just" change some words in a couple of approaches without considering the whole theoretical background), but a group like AEDS could possibly a good home to such efforts.
4. Seen from today's perspective, all existing approaches covered in this contribution – including the author's own attempts (see sub-section 2.5) – are too exclusively "mechanical". What we would need is a sort of extended TTS which is able to also cover mechatronic products, maybe even Product/Service Systems (see e.g. [Weber et al. 2004], [Matzen et al. 2005], [Schendel et al. 2008]). The problem here is that a TTS structure based on the mechanical view of parts structure, geometry and material ***alone*** may be able to also cover electrical/electronic components, but can certainly not cover software and service components.
5. In this context: Which part of possible constituents of TTS (starting from the considerations of Hubka/Eder/Hosnedl, see sub-section 2.1) has the highest priority (or biggest needs): Transformation process model, structuring the technical system according to the stages of the development/design process, structure of system properties, others?
6. Finally, a content-related, but at the same time strategic question: Should Design Theory and Methodology via TTS involve itself more strongly in CAx development and application? If this question is answered with "yes" then again some extensions, maybe even modifications have to be expected.

The development and consolidation of TTS is, in the first place, an academic issue. But how is it related to practical engineering? Interestingly, the area most relevant for practice is the last one mentioned and, at present, the one where TTS is least engaged: providing a sound base for the development and application of software tools and architectures for the support of product development/design processes.

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