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Basic thinking patterns and working methods for multiple DFX

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Abstract
This paper attempts to describe the theory and methodologies behind DFX and linking multiple DFXs together. The contribution is an articulation of basic thinking patterns and description of some working methods for handling multiple DFX.

Introduction

Design for X, where X indicates product life phases like production and service or universal virtues like cost and quality, has to be treated in a multiple way, which means "all together". In practise this constitute a problem, because DFX-methods should be used at the difficult conceptual stage and because there is no convincing methodology for handling more DFX'es integrated or simultaneously.

Today, concurrent engineering is recognised as a substantial methodology for time-rationalisation of product development. In this methodology the life cycle oriented part of the design activity may be solved by taking several DFX into account. Therefore there is a need for a theory or at least an explanation pattern and for thinking patterns and working methods for handling multiple DFX.

Multiple DFX as a problem has been recognised at workshops, Andreasen/Olesen 1993, Meerkamm 1996, 1997 and at the ICED conferences as pointed out by Hubka 1997. The attempts to treat multiple DFX seem to fall into the following classes:

- a co-ordination, "timely" approach, based on insight into which design parameters are related to which product life phases and the life phase system's performance. This approach is design process related, shows consequences and gives advises, see for instance Tichem/Storm 1997.
- a "look ahead"-approach, Borg et al 1997, where decisions about design characteristics are followed up by explicit investigations of their product life consequences, Olesen 1992, Olesen et al 1997.
- a decision making approach, where multi-criteria models of product life consequences are treated for finding the best set of design characteristics, see for instance Gupta et al 1994.

In the following we will try to establish models and explanations, which links these approaches together and to present working methods related to the "look ahead"-approach.

1. DFX is a relation between a design and a life phase

Different types of DFX have reached different stages of maturity and operationability, where for instance DFM was early developed, DFA has found high data support and DFEn and DFQ are newcomers. It is not surprising that there are differing opinions on the nature of DFX:

- A pattern of principles, models, mindsets and methodologies as proposed by Mørup 1993.
- A set of knowledge being the viewpoint of Hubka 1996.
- A forecast and a feedback relation, Wallace 1997.
- A methodology and being a substantial part of concurrent engineering and integrated product development, Olesen 1992.

A specific DFX is an attempt to bring the conditions of the products future life phases into the design activity, for influencing the design activity. So in this article a DFX is seen as a relation between a design and a specific life phase.

Manipulating the design characteristics at the design stage influences the future product life condition, often made visible for the designer by a model of the "meeting". The meeting is the relation between the product, the life phase system and one or more operators, Olesen 1997.

Example: The transport of a large production equipment may be facilitated by transport in a 40 feet container. The designer should therefore structure the machine for partly disassembling and control the process of positioning the subsystems into the container, using trucks and operators.

The basic theories on the relation between a design and a life phase are the following:

- An expansion of the theory of technical systems, Hubka 1988, where *relational* properties (i.e. properties depending on both the product characteristics and the life phase system's properties) are identified, Mortensen 1997.
- The theory of *disposition* proposed by Olesen 1992.
- The concept of *meetings* proposed in detailed form by Olesen 1997.
- The *classes of relations* between product characteristics and life cycle systems characteristics, proposed by Olesen 1992, Fabricius 1994 and Andreasen 1991.
- The *universal virtues* as classes of life phase properties, which may be used as goal specification for DFX, Olesen 1992.
- The *symmetric* nature of relations between the product and its life phase system, Andreasen and Støren 1993.
- The *basic pattern* of a disposition, Olesen 1993.

These theory elements are shown in fig. 1.

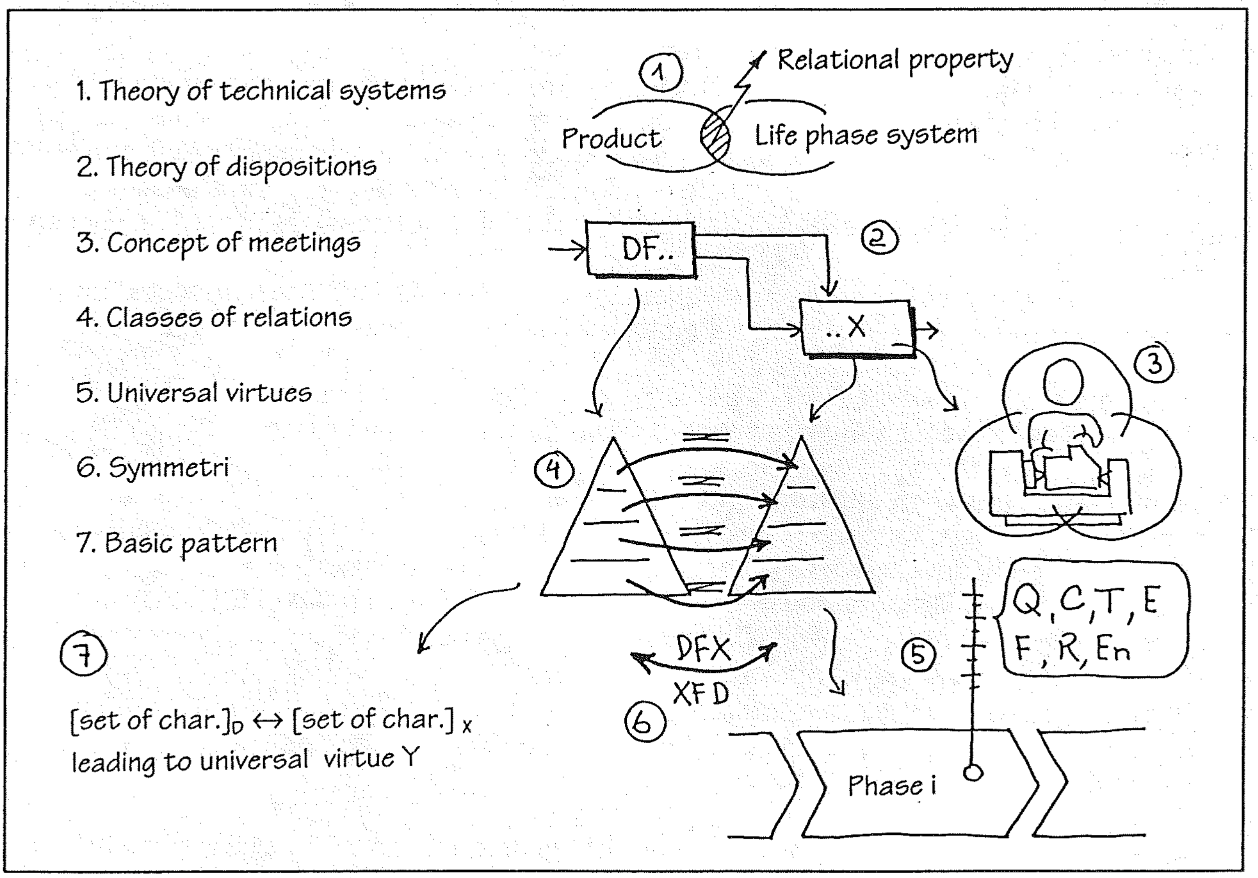

Fig. 1: Basic theory elements of product/life system relations, see the text.

2. ΣDFX means to fit the product to its life cycle

Above we looked upon the phenomena of relations between a product and its life cycle systems. Now we will turn ourselves to the design activities, in which we try to create an ideal fit between the product and the system and to obtain ideal relational properties.

Our basic approach to a DFX methodology is the following: Given a design proposal, we are able to model and analyse it from an X point of view, to make a diagnosis of its fit and X-properties, to advice adjustments and to build these adjustments into the design proposal, Meerkamm 1993.

When using a DFX methodology we manipulate a set of a design characteristics, for instance the part structure, to fit it to a set of system characteristics, for instance the movement pattern of robot grippers. This is based on our insight into DFX principles, telling that a stacked structure allow use of simple pick & place-units, leading to low costs in assembly.
But when we manipulate any set of design characteristics from one X-point of view, we also influence the product's fit to other life phase systems. Our possibility to fit a design to more life phase systems is explained in the theory of superposition of structures, Andreasen et al 1995.

These two viewpoints on DFX and ΣDFX is shown in fig. 2.

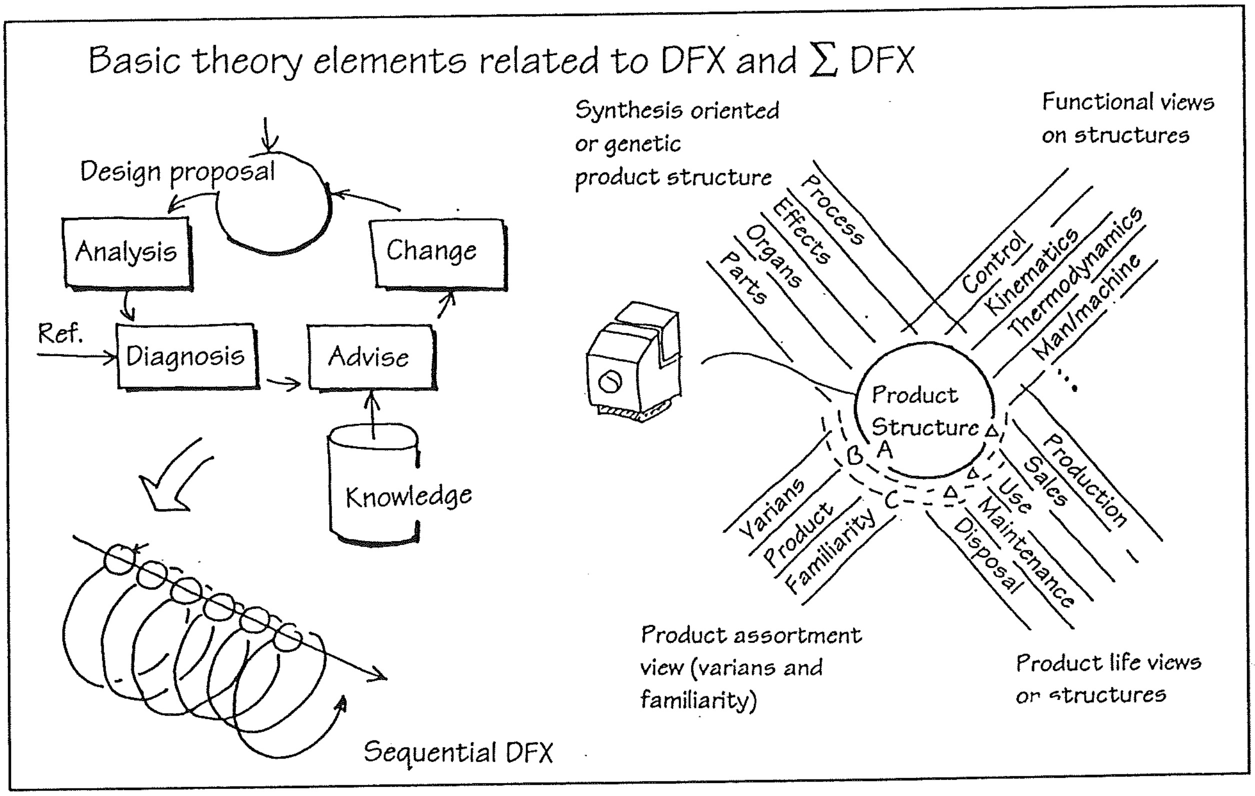

Fig. 2: Design methodology elements of DFX and ΣDFX.

3. ΣDFX on four levels

In the following we will have a closer look upon our knowledge into the relations between a product and its life phase system, following the four classes of relations:

- Strategic/tactical level relations
- Product level relations
- Structural level relations
- Part levels level relations

3.1 Strategic/tactic level relations
Fabricius 1994 call this level company level. At this level the type or nature of the product, which is mirroring a product strategic choice, is related to the strategic choices in other areas, like subsupply, manufacture and sales.

The fitting or DFX-activity at this level is called strategic integration, Andreasen et al 1989 and Andreasen, Hein 1987.

Example (Fabricius 1994): A family of welding machines, structured in such a way that heavier machines consist of a frame plus a number of basic units, are well fitted to a logistic approach, where the sales companies themselves configure the products in accordance to actual customers wishes.

3.2 Product level relations
When we look upon a product family or an assortment of products with variance, we see that the relation between the assortment and product life system splits up into two questions:
- how do we create the variants necessary for the market/sales?
- how do we create such a familiarity between the variants, so that the product life systems are not overloaded?

It is well-known that production systems with high flexibility are a good answer to the second question. Many structuring principles like modularisation and parametric design may answer both questions, see Andreasen et al 1996, 1997. The WDK workshops on product structuring held in Delft may be seen as contributions to treating DFX at product level, or "modular engineering".

3.3 Structural level relations
In the product life phases you see the materialised product, therefore the materialisation pattern is important for fitting the product. At structural level the mechanisms has been fundamentally treated in the paper on superimposed structures, Andreasen 1996 and an overview of structuring theory is given in Andreasen et al 1997.

The DFX activity at structural level is described by Fabricius 1994 and others. Fabricius points out the importance of starting the DFX activity top down, i.e. strategic, product, structural level followed by parts considerations. Tichem/Mortensen 1994 have investigated how lover level DFM depends on higher level product decisions, and Andreasen 1992 has pointed out that there exist distinct classes of solutions of functionality and production method, called "Bauweise", which may be used as knowledge for structural DFM.

3.4 Part level relations
It is well-known that there are important DFX-areas related to manufacturing, where the fitting of parts to the manufacturing and assembly processes are in focus. Here several methodologies exist, some based on principles, other on data.

For the manufacturing area, Jacobsen 1989 has pointed out that the choice of part-form, material and production method cannot be separated. Andreasen et al 1996 has pointed out, how several viewpoints and structural principles may be superimposed and how the designer use an opportunistic viewpoint for designing parts. An attempt to explain the superposition at part level was given in Andreasen et al 1996 in a paper on the nature of features. The functionality contribution from a part stems from product functionalities and functionalities necessary for different product life phases.

4. Working methods for ΣDFX

The available DFX-methods of which some have been introduced above, have the highest effect used top down at the four levels and used at the conceptual stage of design. They are not so easily used in new product development, but have high effects used off-line for creating new concepts.

Efforts of the Department for Control and Engineering Design have not lead to a solution for methodology of ΣDFX, if we request a decision or trade-off support. But several experiences of importance stem from our work with industry, which we will relate to in Olesens score model, Olesen 1992, see fig. 3:

- Design should be seen as a multi-bluck activity, where each bluck has explicit models of what is going on in the actual life phase, described in the domain language of that life phase.
- There should be focused on the relation between the product and the life phase system to enable the participants to see "good" relations.
- There should be worked out explicit concepts for the most important meetings to ensure conceptual good life phase fittings.

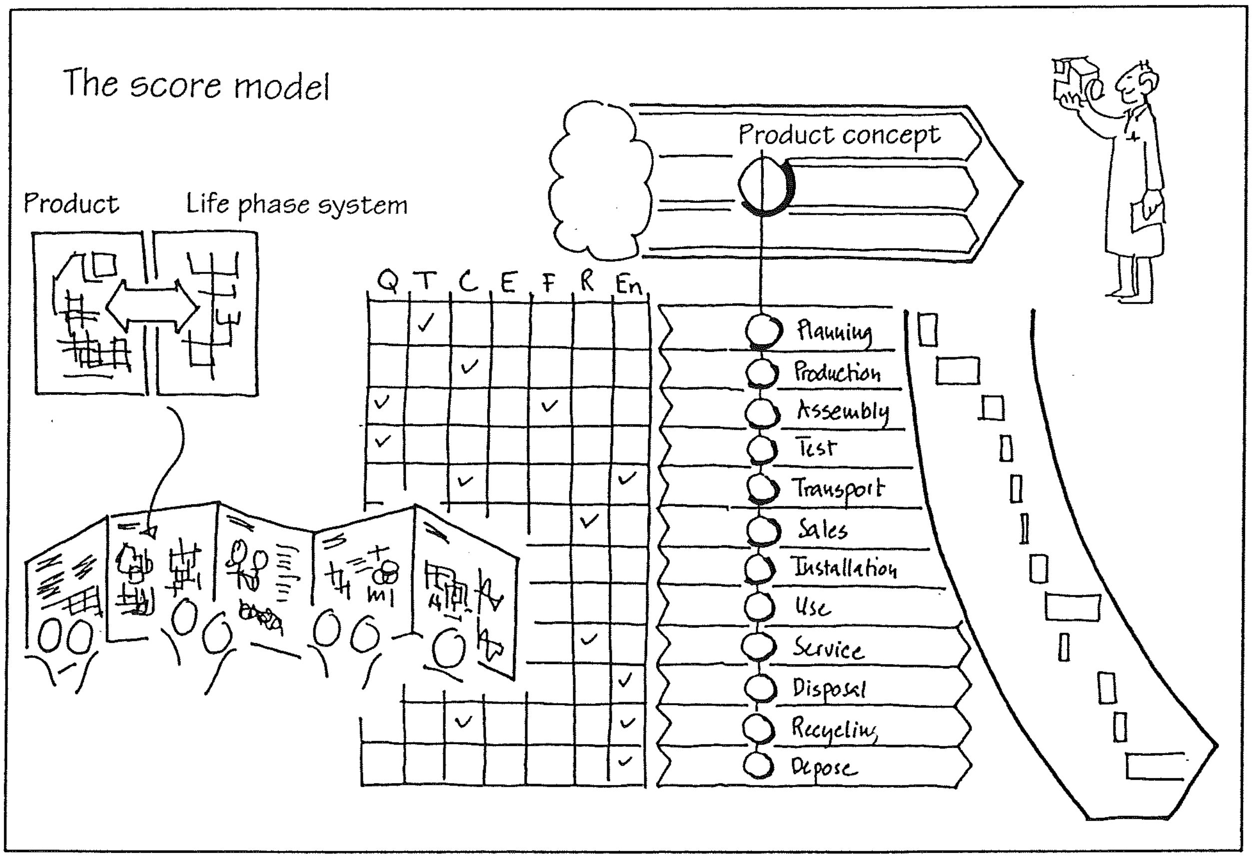

Fig. 3: The score model related to the DFX material and the multiboard concept for designing.

5. Conclusion

This paper took up the question of theories and methodologies related to distinct DFX'es and to ΣDFX, it means solving the integrated product life aspect of designing. We have pointed out that many theories and approaches exist, but that only indirectly, by the choices of the designer, the different DFX'es are linked together, when we look upon "our" type of methodologies. Our basic imagination about an integrated support is to use many, explicit visualisations and to let "product life relevant agents" participate respecting each their domain language. This is the route we choose for further research.

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