

# Constraints and Shortfalls in Engineering Design Practice

Lars Hein<sup>1</sup>, Zhun Fan<sup>2</sup>

<sup>1</sup> IPU, Produktionstorvet, Building 425, DK-2800 Kgs. Lyngby, Denmark.

<sup>2</sup> Department of Mechanical Engineering, DTU, Nils Koppels Allé, DK-2800 Kgs. Lyngby, Denmark.

## Abstract

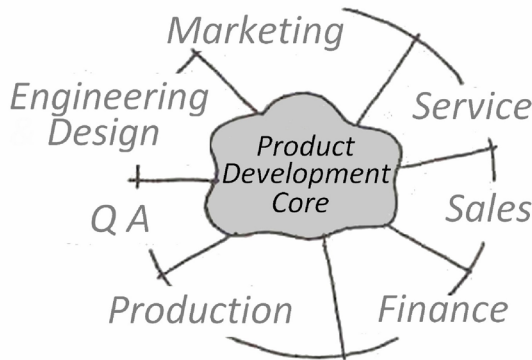
The effectiveness of Engineering Design in practice is what results from a multitude of processes within the realm of Engineering Design itself. However, in order to understand the phenomenon, the processes whereby Engineering Design as a discipline comes together with disciplines from other areas of the company, to sustain the product development process itself, must be taken into account. Therefore, when companies strive to obtain an attractive level of effectiveness of their engineering design activities, the product development process as a whole must be considered. In this paper the first step in an approach by which to optimize the product development process of a company is suggested. This approach makes it possible to arrive at specific conclusions about the constraints and shortfalls of the engineering design activities in a product development context.

*Keywords: Industry, Constraints, Product Development, Engineering Design, Effectiveness.*

## 1. Engineering Design and the Product Development Core

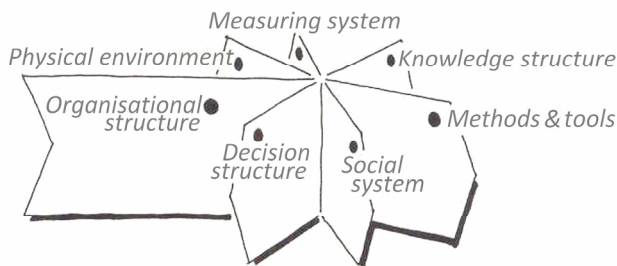
The role of Engineering Design in the innovation processes of a company is a central one. Therefore its effectiveness is of great concern not only to the companies that deals with such processes, but also to those that do research into, and teach within the field of, engineering design.

However, trying to understand its effectiveness from a purely internal analysis of the engineering design processes and activities leads to an unsatisfactory and incomplete picture. An input/output analysis of the Engineering Design Department of a company yields only the most superficial result which it is almost impossible to relate to the overall success of the company. This is fair warning that any attempt to optimize the processes of engineering design on the basis of an internal analysis will lead to suboptimization (fig.1).



**Figure 1.** The Product Development Core (PDC) of a company is where innovation and product development takes place. The PDC of the company has many contributors, not only those formally associated with development such as Engineering Design and Industrial Design.

Some approaches in the research into effectiveness in engineering design deals with relevant engineering design tools and methods, and with the extent to which they are being used in industrial context, some work reporting a low rate of use of the more complex tools [2]. However, what carries the effectiveness of the engineering design and product development processes is more than tools and methods. Generally, at least seven dimensions of the product development core must be considered in order to come to an satisfactory understanding: the organisational structure, the physical environment, the performance measuring system, the knowledge structure, methods & tools, the social system, and the decision structure (fig.2).



**Figure 2.** The seven dimensions of the Product Development system [adapted from 1].

## 2. Constraints and Shortfalls

That the quest to understand the constraints and shortfall of engineering design and of the product development process is relevant is indicated by the frustrations that

are voiced to those who enter into a serious discussion on the subject with people from industry:

- “We don’t get enough from our investments in product development”
- “We use too much energy dealing with our current products, and do not innovate”
- “Arriving at the new products takes us too long time”
- “We do too many new products of the 5%-improvement kind”
- “We have no control over our product cost”
- “The content of new and powerful technologies in our products is low”
- “Our new products fail to realize the market potential”
- “Our new products’ contribution to the company revenue is too weak”

The understanding in the research community of the Engineering Design processes has made remarkable progress in the last ten to twelve years [3]. Thus, there is a potential for this understanding to be utilized to reorganize and reengineer the product development organization in those companies, and to change what is basically an unsatisfactory situation. However, there is no direct relation between realizing that there is a problem, and to the cure that must be specified to actually change the company to increase the product development effectiveness,

This lack of direct correlation between problems and cure is also recognized by the reported work that is being done on metrics and benchmarking of engineering design [4, 5] and metrics of product development [6, 7].

### **3. The Concept of ‘A Diagnosis’**

This paper put forth the hypothesis that, as a first step, a diagnosis may be made on the product development core of a company, leading to an understanding of the underlying illness, or illnesses. This approach is based on the assumption that the product development core of a company share important characteristics with those of a living organism.

The approach is founded on current research based understanding of the product development processes, combined with the accumulated experience of practicing the use of the diagnostic tools and procedures in real companies.

#### **3.1 Understanding the Current Product Development Core**

It is one of the basic assumptions that an indispensable first step is to understand how the existing product development core works, before making a diagnosis. One must be able to understand the composition of the system in the seven aforementioned dimensions (fig.2), and understand how the product development tasks are related to the overall strategies and goals of the company. It is also important to gauge the ‘modus operands and attitudes of key personnel in the

product development core, in order to understand the micro-mechanisms which are the actual generators of innovation and synthesis.

### **3.2 Understanding the Current Problems**

It is another basic assumption that one must understand in detail where the problems lies with the current product development core, before any serious attempt at repair can be made: If we do not understand where the problems are, as a reflection of what the company in its current state is capable of, we will not succeed in creating a new and better product development core.

### **3.3 Seeing the Company ‘Freed from the Ties that Binds’**

Before attempting the diagnosis, one must identify if and where the company has been tied down by unwittingly accepting imaginary boundaries, rules, or norms related to their product development. The diagnosis should rest upon an understanding of what product development could and should be like in the company, freed from those ties.

### **3.4 Understanding the Company’s Environment**

Lastly, the environment in which the company must function must be understood. Important aspects of the environment is:

- The market that the company addresses
- The customers that the company caters to
- Direct and indirect competition
- The nature of the applied technology, and the dynamics involved
- The context and reality of the society where the company must function

## **4. Tools for the Diagnosis**

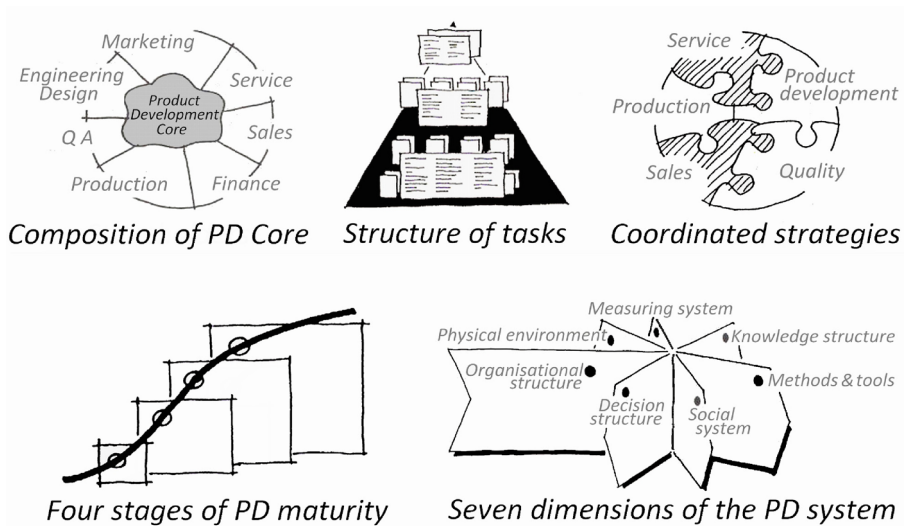
The diagnosis is supported by a number of tools, developed from our current understanding of the engineering design and product development processes. Basically, the tools are organised into three sets: Basic reference patterns, Gap analysis, and the ‘Hypotheses of malfunction’

### **4.1 Five Basic Reference Patterns**

The five basic reference patterns represents five different facets of product development. They are used to compare what is going on in the company with what are generally known to be healthy and productive patterns. Any major deviation from those patterns points to a potential cause of problems.

*Composition of the Product Development Core* deals with the different organisational elements related to the core. How the contributors and stakeholders

interact is highly important to the function and effectiveness of the engineering design activities, and thus scrutiny of the corresponding patterns is essential.



**Figure 3.** The five basic reference patterns used in the diagnosis: Composition of the Product Development Core, the structure of the product development tasks, the set of coordinated strategies in the company, the four stages of maturity of the product development system, and the seven dimensions of the product development system.

*The structure of the product development tasks* deals with the mapping of the often complex pattern of development tasks that the product development core is expected to solve. Here it is important to notice that there are often tasks at both high, medium, and low level in the company, requiring very different competences and measures. A check should be made in order to confirm that the capabilities, resources, and organization are adequate to deal with the tasks with satisfactory results.

*The coordinated strategies in the company* deals with mapping the local strategies of the most important functional areas of the company (typically areas such as Production, Service, Product Development, Quality, and Sales), and checking them for reciprocated consistency and support.

*The four stages of maturity of the product development system* deals with the identification of how far the company has come in its lifecycle, and consequently what the role of the product development core ought to be. Basically, the four stages are: 1. Engineering design stage – the young (and small) company where product development is handled by the engineering design group alone, and where a fair share (if not all) of the commercial awareness is also located. 2. The product development stage - where the technical and the commercial competence and

resources are found in different groups, which must then come together to do product development. 3. The product planning stage – when product development has become so complex that extensive planning and management becomes necessary. 4. The coordinated strategies stage – when further growth and complexity has made the coordination between strong and self sufficient individual departments in the company a major problem.

*The seven dimensions of the product development system* deals with analysing how the company has combined elements from all dimensions into a total working pattern, and of how this patterns compares to the patterns generally known for their functionality, effectiveness, and reliability. Again: Any major deviation from those patterns points to a potential cause of problems.

#### **4.2 Gap Analysis - ‘What We Believe We Are’ vs ‘What We Really Are’**

In a company there may many different (and often conflicting) perceptions by people in different positions about product development - with respect to ‘who we are’, ‘what we are doing’, and ‘how we do it’. And even for all of these individual perceptions, the reality may be something different again. The goal of the gap analysis is to arrive at a realization of the gap between ‘what we believe we are’ from ‘what we really are’.

#### **4.3 Specific Ailments – the ‘Hypotheses of Malfunction’**

Maybe the most powerful set of tools for establishing the diagnosis is the stock of mechanisms notoriously known to generate constraints and shortfalls, previously identified with other companies. The relevant ‘hypotheses of malfunction’ may be selected from the amourey on the basis of the initial findings of the diagnosis, and subsequently put to the test. The proof or disproof of the individual hypotheses will often emerge from interview with key personnel directly involved in the development processes, or with stakeholders in engineering design or the product development results. Currently the stock comprises some 30 to 40 hypotheses, examples of which are:

- “Not enough management focus on product development.”
- “A lag of engineering competences in respect of the tasks to be performed.”
- “The role of engineering design and/or product development in the company is unclear”.
- “The goals set for engineering design activities are weak and unambitious”.
- “No link from company strategy through to the engineering design and product development activities.”
- “The engineering design department is tied down by old debt (= previously unfinished, but unproductive work).”
- “The chair of the engineering design manager (or of the product development manager) is empty.”

- “The handbook and the procedures for the product development process are being ignored.”
- “In the projects, the information related to market and customers is not forthcoming, or is weak and unsubstantiated.”
- “The business acumen has been stifled by bureaucracy.”

## 5. Testing the Concept, Tools and Procedures of the Diagnosis

Over a period, the concept of ‘diagnosis’ has been put to the test, and the tools and procedures described above has been tested, modified and optimized.

In all, more than fifty companies, of sizes from a few hundred to many thousands employees, has had a diagnosis made either by our group, or by our cooperation partners. The companies have predominantly been manufacturing companies, with a number of service-industry companies also present.

The diagnosis was being performed always by two researchers as a team, and in no instances were they themselves employed by, or affiliated with, the company.

The presentation of the findings of the diagnosis to the company followed always the same pattern: The findings and conclusions was written up in a formal report, and subsequently presented to the management board - in some instances this group was supplemented by key personnel from engineering design or from the product development core. The management board then discussed the diagnosis, and, as a rule approved the findings and conclusions. The result was then communicated to all relevant staff, and the next phases, those concerned with the re-engineering of the organization, could begin.

The conclusion of the test is that the diagnosis arrived at was approved by the individual company in over 90% of the cases. In more than 80% of the cases the go-ahead was given for the subsequent organization re-engineering activities.

## 6. Conclusions

In order to deal with the constraints and shortfalls in engineering design practice, the processes by which Engineering Design comes together with disciplines from other areas of the company, to sustain the product development process itself, must be taken into account.

The accumulated results of research into Engineering Design and product development is now adequate enough that it may provide the basis for the development of a structured process by which to reduce or remove the constraints and shortfalls in engineering design practice. However, the application and training

of this process in real companies is required in order to adapt and make operational the suggested tools and procedures.

In this paper, the first step of such a structured process, *the diagnosis*, is proposed. Through rigorous testing in companies in the Nordic countries, the concept of Diagnosis and the corresponding set of tools and procedures has been adapted, and been demonstrated to yield productive results.

Future research should focus on the remaining steps in the process. In addition, the testing and practice of the process should be used to collect data for the subsequent generation of metrics by which to benchmark the engineering design capabilities and effectiveness of a company, to add to the data repository in this field.

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