# METHODOLOGY FOR THE EVALUATION OF THE FLOW OF INFORMATION IN THE PRODUCT DESIGN PROCESS

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## Abstract

The product design process, as the backbone of the product's success in the market, consists of the generation, the handling and the dissemination of information in an interdisciplinary team. The deficiencies in the flow of information within the company or the involved product design team may result in time-consuming product changes and sub-optimal solutions.

This paper presents a methodology to investigate the communication and the flow of information within the company and between companies in the field of product design. Therefore a structured and methodically based approach is presented. It consists of the steps:

- Identification of the existing information structure

- Identification of the information needs of the involved team members

- Stepwise improvement by the use of the Communication & Information-Model (called KIM – Kommunikations- und Informationsmodell) that consists of two parts:

    1. A support tool for the operative product design

    2. An assessment to evaluate the C&I-capability of the company in the field of product design

The methodology has the objective to create a company specific C&I-concept. The purpose of the concept is to give the company the opportunity to improve the product design process stepwise. Decisions for the investment in C&I-improvements become calculable and comparable.

*Keywords: Flow of Information, Information Map, Product Design Process, C&I – Model KIM*

# 1.   Introduction

The economic success of manufacturing firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low costs [1]. The dynamics in the market, the globalisation and the increasing customer requirements are additional basic conditions, which have to be considered in the current situation of product design. The prerequisites and keys to reach product success are product quality, sales price, lead time and development cost. The effective and efficient flow of information and communication within the product design team are the prerequisite to reach all of them. In this paper we address this topic and present a methodology to improve the C&I-solution within the company.

# 2.  Area of Interest

This paper addresses the flow of information in the product development process of the innovation process [2] in the context of an interdisciplinary and distributed project team, consisting for example of the functions sales, engineering, production, purchasing and quality assurance. The product design process in this context has a high complexity and a huge communication expense [3]. The methodology presented in this paper can be used to analyse and improve the C&I-capability within the company or even to coordinate the work between different companies in the field of product design.

## 2.1  Definition and Classification

To understand the meaning of information it is useful to describe the functional chain between symbols and knowledge according to [4]:
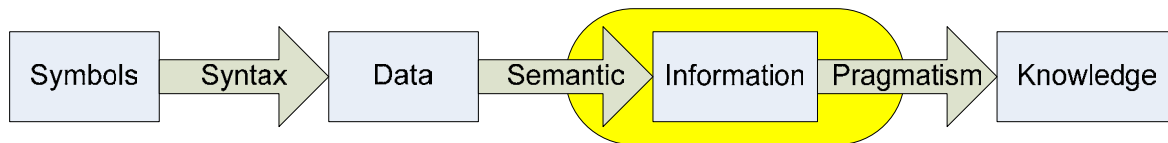


Figure 1: Functional Chain from Symbols to Knowledge

Information is based on data that is in a special context for the recipient information. The mentioned context is that the message comprehends novelties for the recipient that is useful for the current situation. In the product design context, the information should be used in the commercial or technical problem solving or decision making.

According to Davenport [5] information is described as a message that can be documented in written or acoustic or visual form. Therefore information has a sender and a recipient. Generally the recipient decides whether the data is information or not.

Zehnder [6] defines information as the answer to a concrete question.

To manage the complexity in the flow of information, one approach is to classify the information. Some possibilities, especially for product design, are presented as follows:

The first possibility to classify information is according to DIN 6789 (see Figure 2). The purpose is to classify the main area of interest; namely product information.
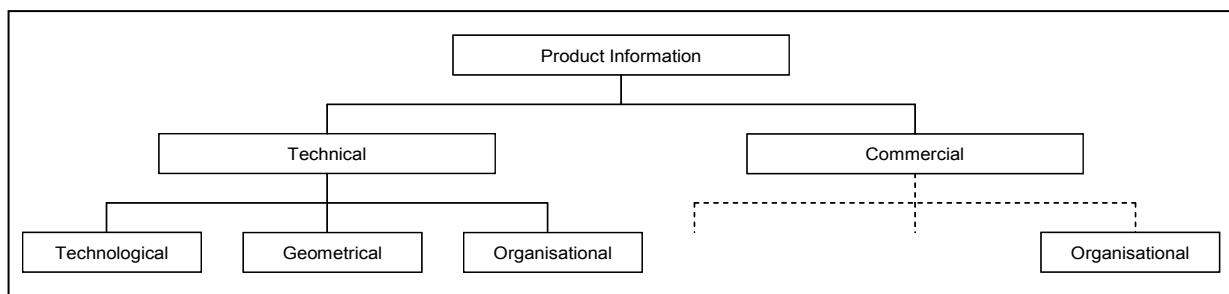


Figure 2: Classification according to DIN 6789 [7]

Eigner et al [8] uses the classification of DIN 6789 and adds some new aspects, see Figure 3.
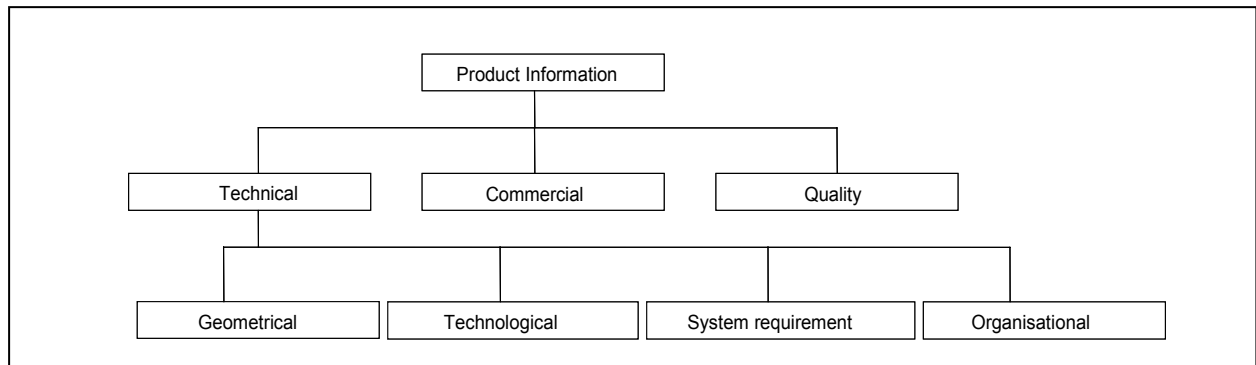
Figure 3: Classification according to Eigner et al [8]

Based on the classifications above we want to divide information in the product design mainly into two different areas:

- The area of product relevant data: Information that can directly be assigned to the product structure

- The area of project relevant data: Required information that cannot be assigned to the product structure

Documents are the case sensitive collection of information in a closed embodiment. The border case of a document consists of one piece of information.

## 2.2   Information in Product Design

The information created, handled and communicated within the product design process is very heterogeneous. The project starts with the first information about the need of a new product (based on existing information or experience within the company) and ends with the final documents for the serial production. Within this time period, a huge amount of information must be managed. Another important fact is that the information content is dynamic. The status of information does not stay the same; there are changes for example in the product specifications or the manufacturing processes or technologies, which influence other information as well. The control and the tools to manage the flow of information are the keys to success for every product development. Information is an essential prerequisite for the functioning of the organisation and processes in product design [9].

A fragmentary overview for the information handled in the product design is the following listing of identified documents:

- Requirement Specification

- Product Model Data (3D, 2D, Drawing)

- Functional Specification

- Norms, Guidelines, Patents

- Demand for Revision, Change Order

- Orders

- Offers

- Commercial and Technical Correspondence

- Test results

3

- Production Plans
- Schedules
- …

In the practical work for the KIM project, we identified at least 50 different documents within a product development for a single level of the supply chain in the automotive industry. These documents consist of an average of 20 different information items, so that the sum of handled information is around 1000 for the official documentation process, not taken in consideration the dynamics of the information content.

## 2.3   Flow of Information

The information is generated by a project team member within a special task and is then transferred to another task or stored within a database for electronically available information or a special location for non-electronically available information. Depending on the content of the information, other team members access the information again. The information is protected or transferred or changed within different tasks of the product design process. This procedure, described above, is called the flow of information. Communication is a synonym for the flow of information.

Information Need of the Interdisciplinary Project Team

The people within the product design team have different functions. The complexity of product design does not permit that one person fulfils all the necessary tasks. Therefore the responsibilities are shared and managed by the definition of the company's organisation structure and the process organisation as well as the use of project management methods. Due to the dissemination of the duties and responsibilities, the different team members have different information needs.

For the following considerations we will use the process view of the flow of information and additionally the decision related information [10].

Aspects of Dynamics: Product Design Process

The common method to control the product design process is a clear process description. The flow of information within interdisciplinary project teams can be orientated at the tasks (work that has to be performed, for example "preparation of the product model with a CAD – system") and the involved team members per task. Due to this reason it is useful to analyse which information is needed to perform the work within a single task. On the other hand, the work performed within a single task also produces some kind of information. This output information is the input information of a later task. With this easy and obvious consideration, it becomes possible to analyse the dynamics of the flow of information.

Aspects of Decision-Making

Decisions (choices between possible alternatives, for example the decision about the material of a single component of the product) within the product design should be based on an adequate information base. The information needed for a qualitatively good decision has to be analysed and the decision maker must be supported by the possibility to get the required information in the required quality, quantity and with the right timing [4, 11].

# 3. IT – Support for the Communication of Distributed Project Teams

The deficiencies in the flow of information within the product design must be analysed, an information concept must be implemented and can then be supported by the use of commercial IT-tools. The following IT-tools represent the most common systems in product design.

Systems for the creation or handling of information:

- CAD   Computer Aided Design
- CAE   Computer Aided Engineering
- CAM   Computer Aided Manufacturing

Systems for the management of information:

- PLM   Product Lifecycle Management
- ERP   Enterprise Resource Planning

In the extended scope of PLM there are additional functions like SCM (Supply Chain Management), RTM (Requirement Traceability Management) or CSCW (Computer Supported Cooperative Work) [8].

# 4. Assessment of the Efficiency of Product Design

The main indicator of efficient product design is the later success of the product in the market. The relation between the flow of information within interdisciplinary teams in the phase of the product definition and the later success cannot be proofed on a direct way. The following indications should confirm the relation:

- The lead time is a main indicator for the product success [1]. Efficient flow of information helps to reduce the lead time because it avoids time-consuming product changes.

- The quality of the product, the fulfilment of the customer requirements, depends on the flow of information between marketing, engineering, production and sales. This leads to satisfied customers.

- The efficient flow of information helps reducing the product manufacturing costs, because the product features are designed-for-manufacturing or designed-for-assembly [12]. This can lead to lower sales price or higher revenue.

In the following, we will introduce a state-of-the-art assessment for process management. Other possibilities to evaluate the process definitions would be the comparison with international standards like ISO9000 etc. within a certification process, but this is not the subject matter of this paper.

CMM – Capability Maturity Model

The Capability Maturity Models (CMMs) contain the essential elements of effective processes. These models have their origin in the software development. The newest approach in the CMM-development is called CMMI (Capability Maturity Model Integration). Since 1991, CMMs have been developed for different disciplines like systems engineering, software engineering, software acquisition, workforce management and development and integrated product and process development. CMMI is the attempt to focus the improvement efforts of

the different disciplines and sort out the problem of using multiple CMMs within the company. [13]

The idea behind CMM is to arrange all the elements, important for capable processes in a model with different maturity levels. The company is then able to identify the maturity level reached and to elaborate all the necessary improvement measures for the next level.

The CMMI has a continuous and a staged representation. The components of both representations are:

- Process Areas

- Specific Goals

- Specific Practices

- Generic Practices

- Typical Work Products

- Sub practices

- Notes

- Generic Practice Elaborations

- References

The maturity levels of the staged representation are:

1. Initial
2. Managed
3. Defined
4. Quantitatively Managed
5. Optimizing

In this paper, we present a method to use this approach to improve the communication and information capability of the company. We will show new aspects and an advanced approach especially for the product design.

## 5. KIM - Description

The KIM-approach is based on a methodology to improve the flow of information and the communication within the product design process. Investigations in the context of the KIM-Project have shown that only a holistic view of the information and communication is capable of improving the product design.

Therefore the approach is divided into two main aspects (see Figure 4):

1. A support tool for the operative product design: KIM supporting the product design projects

2. An assessment to evaluate the C&I-capability of the company in the field of product design: KIM assessing and improving the C&I-infrastructure of the company
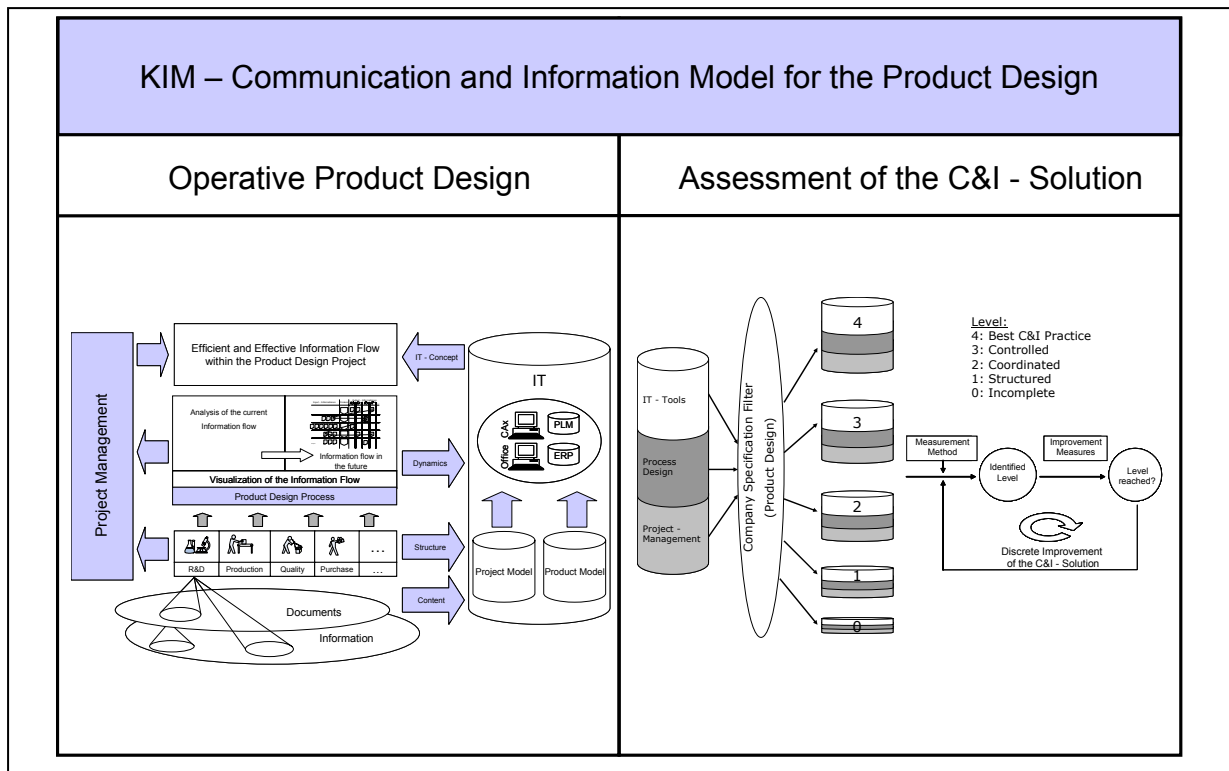
Figure 4. KIM-Communication and Information Model

## 5.1 Operative Product Design

The first model has the focus on the operative everyday work within interdisciplinary project teams. With this model, we want to reduce the complexity in a multifaceted environment like product design. We are focusing on the information that is required to perform the tasks of different functions. Therefore the presented model is divided in different modules (see Figure 5):

- Information level of product design
- Documentation level (information that is available and structured in documentation format)
- Information need of the involved team members (functional dependency)
- Visualization of the flow of information: information map
- Control of the flow of information within the product design project

The model is a simple visualization of the situation in highly complex product design projects as well as a straightforward methodology to improve the communication and flow of information within the design project. The steps to use the model in operative work would be:

- Identification of the required information
- Identification and Analysis of the documentation
- Identification and Analysis of the information need of the involved team members (tasks and decision aspects)
- Visualization of the flow of information in an information map

- Coordination of efficient and effective flows of information with the help of project management techniques and the IT-infrastructure, that consists of a project model and a product model as well as the IT-tools of the company
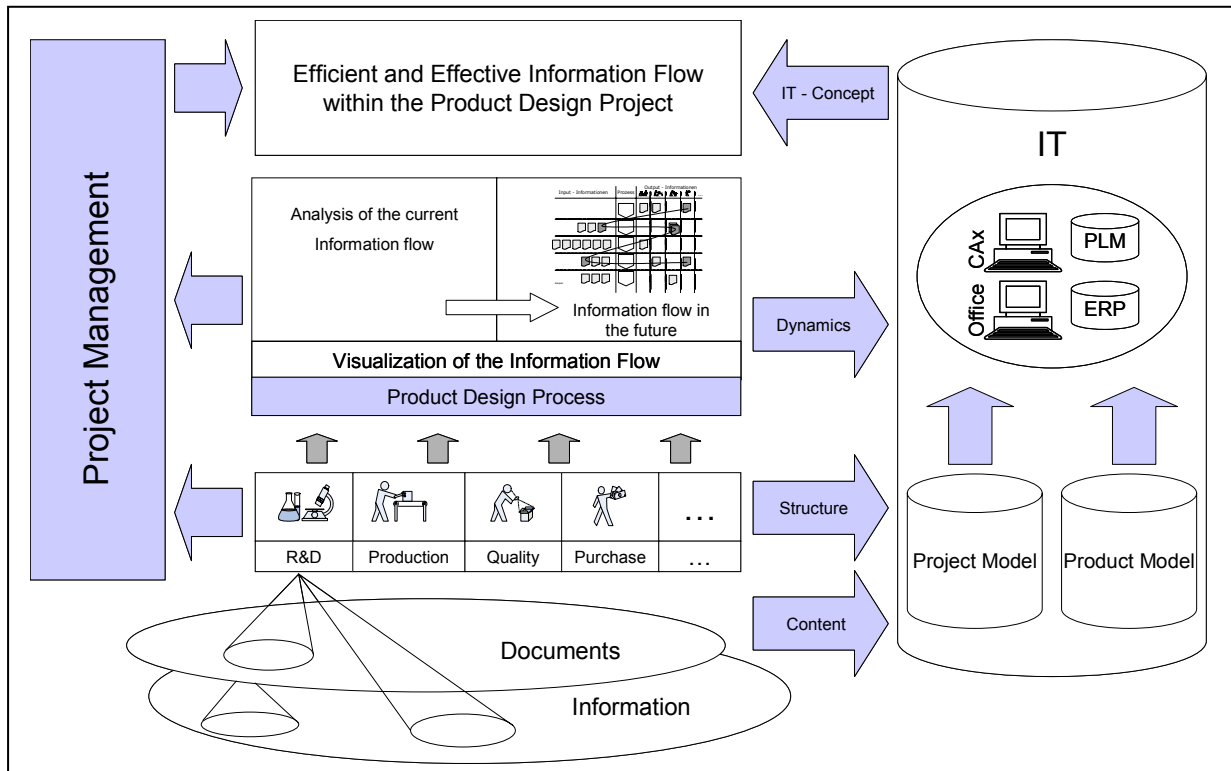


Figure 5: Operative product design

To understand and explain the model of the operative product design, the following sections give a deeper explanation.

### 5.1.1 Information Level

The information level in the operative product design model has the purpose to contain all the information required during the product design process. The information can be structured or unstructured, formal or informal. For the analysis and identification of the required information the following procedure is proposed:

- Analysis of the information by interviewing the involved functions

- Analysis of the common documents within the company in the field of product design (for example requirement specification, project description, product information, etc.)

- Analysis of the interface comprehensive information between functions

- Identification of the process relevant information

- Identification of the decision relevant information

Identification of the process relevant information

The most companies have, for example as a result of ISO9000 [20] certification, a process description for the product design process. This process description can be used as a basis to analyse the input and output information that is needed to perform the proposed tasks.

Identification of the decision relevant information

The decisions in product design can be analysed by the following scheme:

1. Identification of the product relevant decisions related to the product characteristics
2. Identification of the commercial decisions
3. Identification of the organisational decisions

## 5.1.2 Documentation Level

The level of documentation within the C&I-model (KIM) represents the logic that the formal information in product design is concentrated and structured in documents. The documents can be identified by the analysis of the documentation of the company. This also gives the chance of improving the company's documentation by the elaboration of forms and drafts for the documentation process.

## 5.1.3 Information Needs

As mentioned before every function in the product design has a special information need. The information need depends on the responsibilities of the role as well as the knowledge of the individual. The identification of the information need can be supported by different methods for example the use of questionnaires or a brainwriting-method, interviews, external or self-monitoring [14, 11].

The proposed method in this paper is the first information-matrix (see Figure 7: 1). The dynamic aspect of the information need is visualized in the information map. The procedure in identifying the information need starts by the elaboration of the information map. The first information-matrix is a result of the information map.

## 5.1.4 Visualization of the Flow of Information

For the visualization and the modelling of information there are different methods in use. Some methods should be mentioned in the following. Established data modelling languages are NIAM, ERM, UML, IDEF0 and EXPRESS [6, 15, 16, 17, 18]. These methods are used for the static data modelling in the context of software development mainly for the use of data base design. Process oriented methods are for example flow charts, Petri nets, design structure matrices or SADT [1, 19, 11]. The advantage of these methods is the representation of the dynamic that is needed to represent the information flow. The presented method within this paper is similar to the process oriented methods but has an additional focus on the flow of information. Therefore we position a linear process description in the centre of the visualization. Both sides of the information map are designed as matrices to map the elaborated information to the involved function. The flow of information can be analysed and visualized within the information map for a single piece of information.
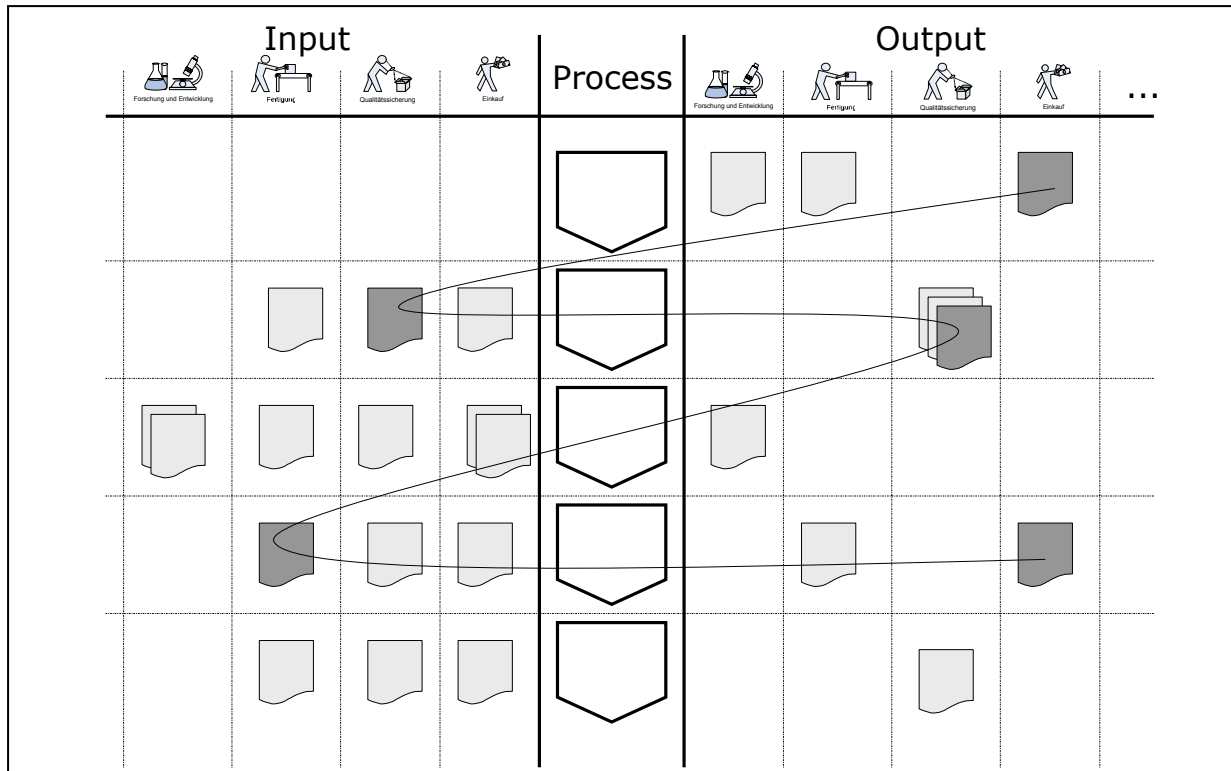
Figure 6: Information map

### 5.1.5 Analysis of the Flow of Information

The next step in the analysis of the flow of information in the design process is the derivation of the information matrices that give an overview of the importance of the information in the product design process (see Figure 7). This step can be automated by an IT – based solution. The IT-tool can support the automated generation of the information matrices using the information map. The first information matrix (see Figure 7: 1) provides information about the access to a specific piece of information by a specific function as well as a summary of the involved functions and pieces of information. The quantitative amount of access to a piece of information is summarized in the last column of the matrix. This gives an indication of the importance of the piece of information. The sum of the access by function in the last row of the matrix is a quantitative indicator about the information need of the function.
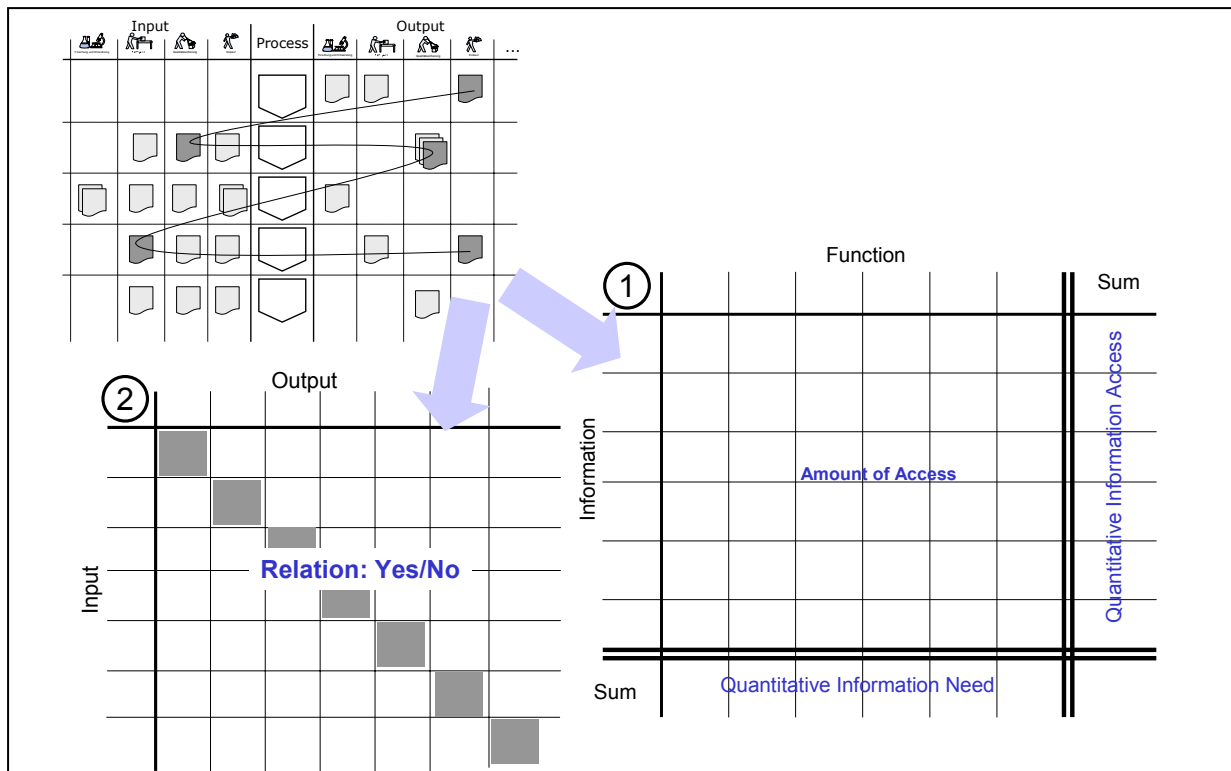
Figure 7: Derivation of the Information Matrices

For an additional possibility of analysing the flow of information within the product design, the next interpretation is the second matrix (see Figure 7: 2). This matrix shows the relationship between different information. This nxn-matrix consists of the pieces of information in the rows as well as in the columns. The field shows the relationship between information. More precisely the relation between the input piece of information that is used within a task to elaborate the corresponding output piece of information. This can be useful for example for the change management, if you have to analyse the consequences of a change for other pieces of information.

## 5.2 Assessment of the C&I - Solution

The second module of the C&I - Model KIM is an assessment of the C&I - solution within the area of product design. This assessment shall allow identifying the strength and weaknesses of the current C&I - solution within the company. Therefore we identified three areas of interest that influence the communication and the flow of information:

- IT - Tools
- Process design
- Project management

These three areas also represent the interface between the operative product design and the assessment of the C&I - solution.
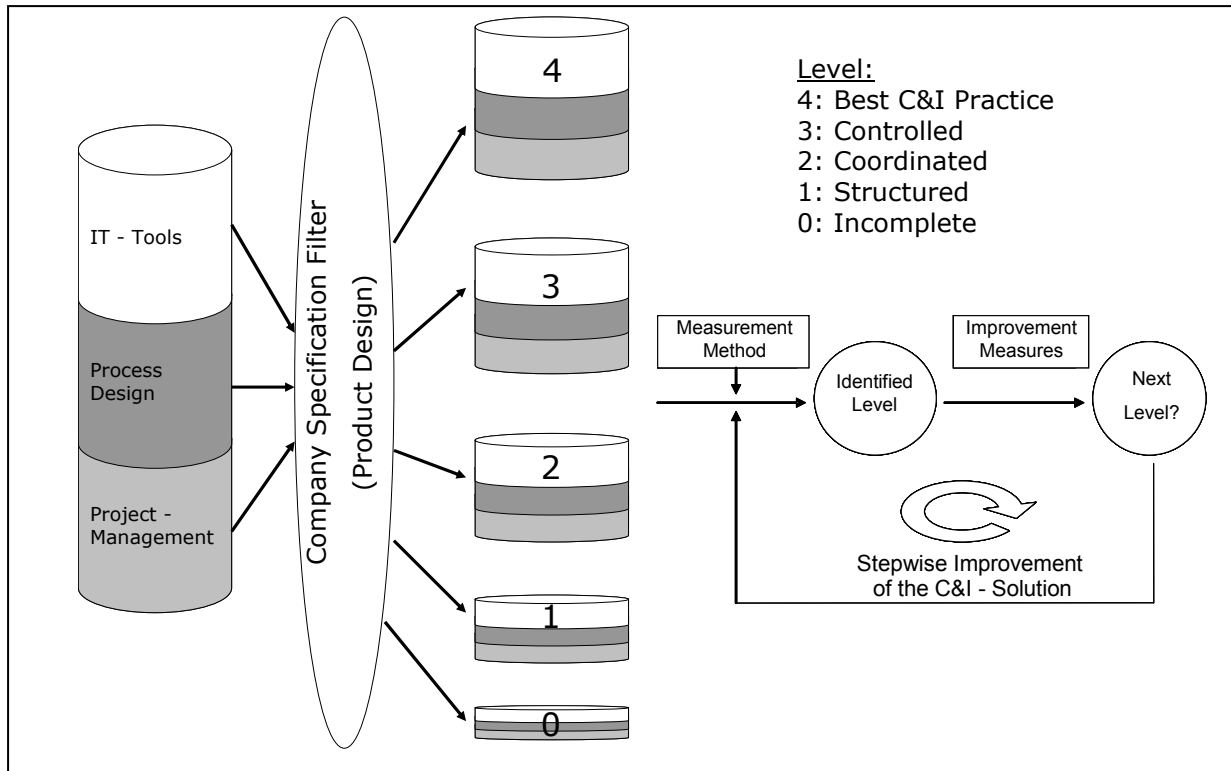
Figure 8: Assessment of the C&I – Solution

### 5.2.1 3 Areas of interest: IT - Tools, Process design, Project Management

In the area of the IT-Tools the main foci are the elements and characteristics of state-of-the-art IT - support for the product design. So the area IT-Tools contains all functions and traits that are correlated for example to the efficient use of Product Lifecycle Management - Tools or the use of CAx - Technology etc.

The Process Design area therefore consists of all elements linked to the process description and the practical use of processes in every day work in the field of product design. It contains for example of elements like the implementation of process design or the use of a company specific tailoring system to define a unique project.

The last area is the area of Project Management (PM). In this area we summarize the elements related to the organisation of the product design team and the human aspects of the C&I - solution like human communication and communication concepts. As well as the used PM - methods or the existing communication culture.

### 5.2.2 Company Specification Filter

The elements of the three areas IT - Tools, Process Design and Project Management shall be positioned to five levels of the C&I - capability of the product design. This mapping is highly company specific and therefore not generic. To solve this problem we defined a company specification filter that allows identifying how important a single element is for the subject company. This filter assigns the elements to its level of maturity.

The company can identify its profile by choosing the correct characteristics (see Table 1), therefore the elements are linked to a single or a combination of characteristics.

Table 1: Extract of the Company Specification Filter

| | Characteristics | | | | |
|---|---|---|---|---|---|
| **Basic Conditions** | **General** | | | | |
| | Product Type | Mechanical | Electronic | Software | Service |
| | | | | | |
| | Product Structure | One-piece | Multi-piece with an easy structure | | Multi-piece with a complex structure |
| | **Product Design** | | | | |
| | Size of the PD - Team | 2-10 | 10-20 | 20-30 | >30 |
| | Organisation within the PD | Line Organisation | Matrix Organisation | | Project Organisation |
| | Starting point of PD | Product Idea | Requirement Specification | Concept | Order |
| | Dimensions of the PD | Local | National | International (2 locations) | International (>2 locations) |
| | Supply Chain Position | OEM | 1. Level | 2. Level | 3. Level |
| | Number of Suppliers | 0 | 1-5 | 5-10 | >10 |
| | Supplier with Responsibility for Product Design | 0 | 1-5 | 5-10 | >10 |

## 5.2.3  The Evaluation and Improvement Process

The next step would be the comparison of the elements that are installed within the company to the different levels. If a company has all elements of a level and the levels below, it can be positioned at least to this level. The elements of the next level are known and the difference can be identified. The company knows the elements that are missing to reach the next level and can define the improvement measures to reach this level. The company also has the possibility to make a cost - benefit calculation for the next level and can decide if it is worth for the company to reach the next level of the C&I - capability.

# 6.    IT – Support for the KIM Methodology

It is proposed to use an IT - based tool for the collection and the management of the information and the execution of the KIM - methodology. The user interface of a tool based on a relational database is presented in Figure 9. The tool represents the complete methodology from identifying the relevant information (1) to the definition of the project profile from a reference process profile (2) and the allocation of input (3) and output information (4) per chosen task and their visualization in an information map (5).
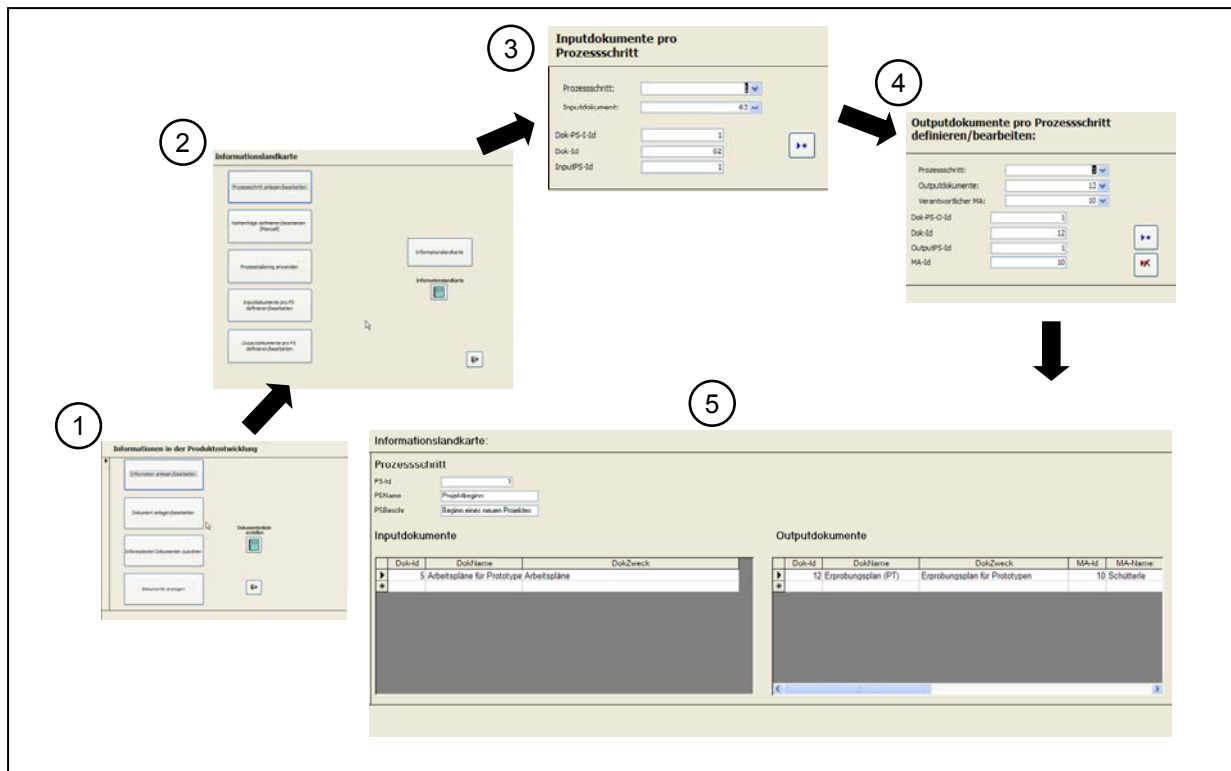
Figure 9: IT – Support for the C&I - Model

# 7. Conclusion

The dynamics in product design demand an improvement in the communication and the flow of information in an interdisciplinary project team. Therefore a support for the operative product design process as well as a company specific assessment methodology is required. The presented C&I - model includes both aspects and has reached the necessary maturity to be applied in operative product design. In the ongoing KIM - project the methodology is evaluated during a time period of two years and permanently enhanced. The next steps in the KIM - development will be the implementation in companies from different industries, the advancement of the KIM - tool to support the implementation process as well as the operative work with the KIM - methodology, the enhancement and completion of the company specification filter as well as the identification and collection of relevant elements for the assessment of the C&I - capability.

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