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# CAPTURING THE FLOWS OF THE PRODUCT PROCESS

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## 1. Introduction

The traditional knowledge technology expects that information could be represented with static meta structure which can be managed and refined by classifying and arranging. In this kind of approach the usability and the actual value of the information depends on correctly chosen and formulated key fields and workflow which support the activities and maintaining of information valid and in correct format.In this paper we want to raise the discussion and to challenge this traditional view. The development trend, using static meta structures that were useful when they were created might turn into burden instead of advantage.

Increase in quantity of information will result in challenges in administration. This can lead to the fact that for the storing of the information there is necessarily no suitable location by the information systems for example. Without the resources required for the administration and without the know-how the information in the systems can be out of date. From this it follows that the adapting of the information at the later stages of the product life cycle will cause unnecessary iteration and making of engineering changes with the sectors which the information in question affects.

We approach this problem in a case that is related to the car industry. In this case we are dealing with the early phases (planning and development) of the product process. Modelling of the process which creates released design information for engineering change management is emphasized.

The structure of the paper is following: Research method is introduced in Chapter 2. The case being studied and the research questions are discussed in Chapter 3. Literature review is done in Chapter 4. Propopositions to the research problem are represented in Chapter 5. Findings and alternative approaches are covered in Chapter 6. Conclusions from the findings including answers to research questions are written in Chapter 7.

## 2. Research method

Case study research method [Yin 2009] is utilised in this research. The phases of this method are listed in Figure 1 and described briefly in the following: Research questions are identified in the planning phase at first. Case(s) to be studied, propositions and ways to analyse the quality of research designs are defined in the design phase. The essential in prepare phase is to form a case study protocol that is utilised in collect phase when the evidence is found out. The evidence is analysed in the next phase. The case study is reported after the analysis in the last phase. Some of the case study process elements have feedback loops as it can be seen from Figure 1. These loops should be utilised when one is doing multiple case analysis especially.

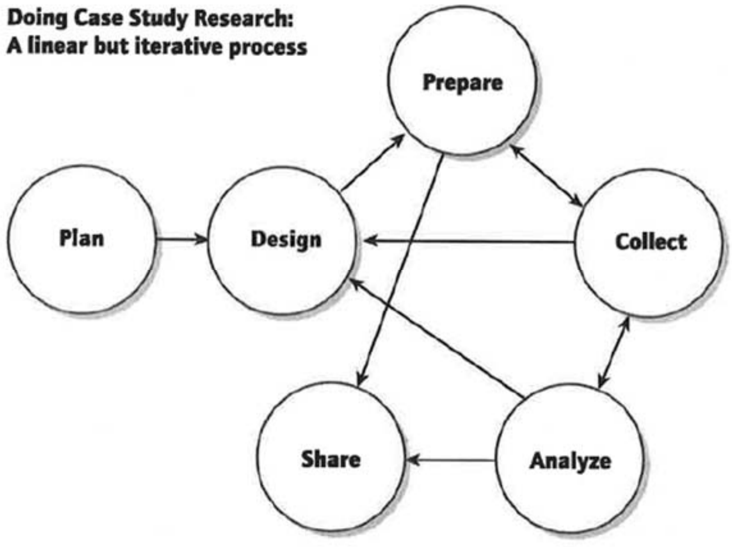



**Figure 1. The case study research process [Yin 2009]**

## 3. Case company and research questions

This paper represents a single case study done in a car manufacturing company Valmet Automotive. The company has been manufacturing cars for over 40 years for traditional OEMs. In its manufacturing role the company has also been using more or less simultaneous engineering by designing the production process at the same time as the product is being designed in collaboration with the OEM. In the beginning of the 21st century the company's strategy was expanded from contract manufacturing to service providing. Soon after that the customer profile has been changed from traditional OEMs to brand new OEMs developing cars of the new era, e.g. electric and hybrid cars. Examples of products are shown in Figure 2.


**Figure 2. Top row includes models of traditional car manufacturers for example Saab and Porsche that the company has manufactured earlier. Bottom line shows models of newer companies Garia and Fisker which Valmet Automotive produces**

The new companies have different way to develop the product than the traditional ones. Their development project is less formal and does not follow strictly a project quality gate model which is commonly used by traditional OEMs.
The case company has experienced the use of stage-gate systems with several earlier OEM customers and their new products. The company calls it quality-gate system. The new trend is that the product development project proceeds more or less in a lean and agile way. There are no clear gates where different checklist tasks are being performed and marked as "done" when carried out. Under these circumstances it is challenging to follow up the changes in the EBOM and the product – problem is that it is difficult to estimate when certain information element is available to be used and when and where in the product process (the steps needed in realising the product) it is needed. This is important, when the production process is being designed simultaneously with the product development. Figure 3 is representing the change in the way how product development and production has been changing under the time-to-market pressure in car industry.

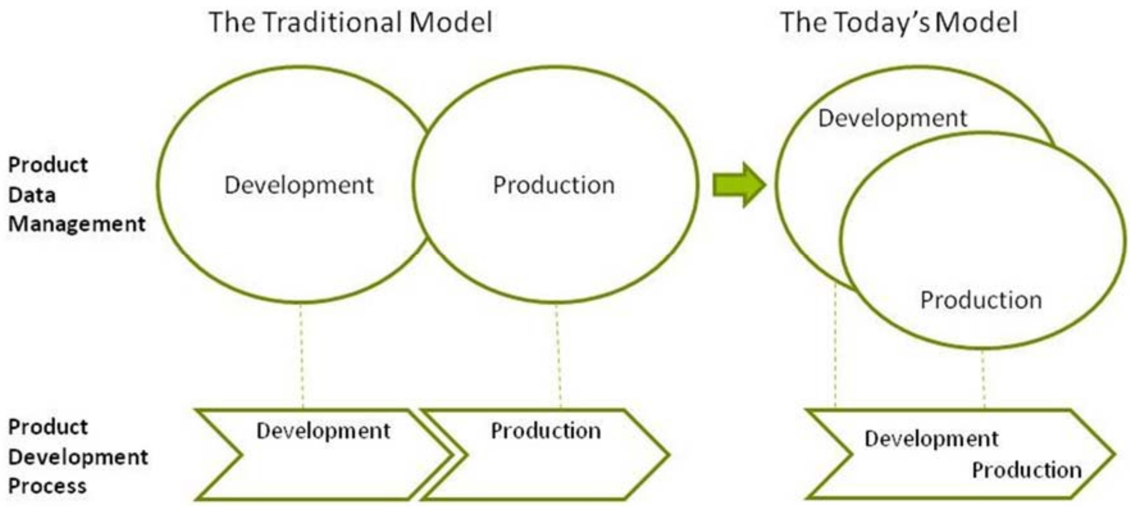



**Figure 3. The incidence of lifecycle system at the change of the product lifecycle change; the traditional and target model. Adapted from [Huhtala and Pulkkinen 2009]**

Research question was identified based on the challenges in tracking the status of information and its usage mentioned earlier in this chapter: How to analyse the information completeness in the product process?

## 4. Scientific background

Literature review has been divided into three subsections. Stage-gate processes are discussed first. Then modelling of product processes from the information perspective is represented. The third subsection focuses on information completeness models. Summary of the literature review is made at the end of this chapter.

### 4.1 Stage-gate product development processes

Cooper [1990] has been researching the stage-gate system in projects which deal with new product development. He has written that corporations were increasingly looking to stage-gate models as an effective tool to manage their product innovation projects. Figure 4 gives an example of gates and stages that the stage-gate system usually includes. The issues that have been made at the stage in the gate models are checked in a gate and a decision on continuing the project is done. The stage-gate system is a conceptual and operational model for moving a new product from idea to launch. Cooper says that the system is one answer to better manage the innovation process.
The stage-gate system has been widely used in car industry. Cooper [1990] talks about Four Phase system of General Motors (GM) which is their version of stage-gate system. In that system car development process has been connected to the organization hierarchies of the company. Each

hierarchical levels have their own milestones. Updating the contents of the gates and milestones has been done during the years, for example because of the advances in virtual development solutions, but the main idea in the stage-gate process of GM has stayed as the same [Teske 2007].

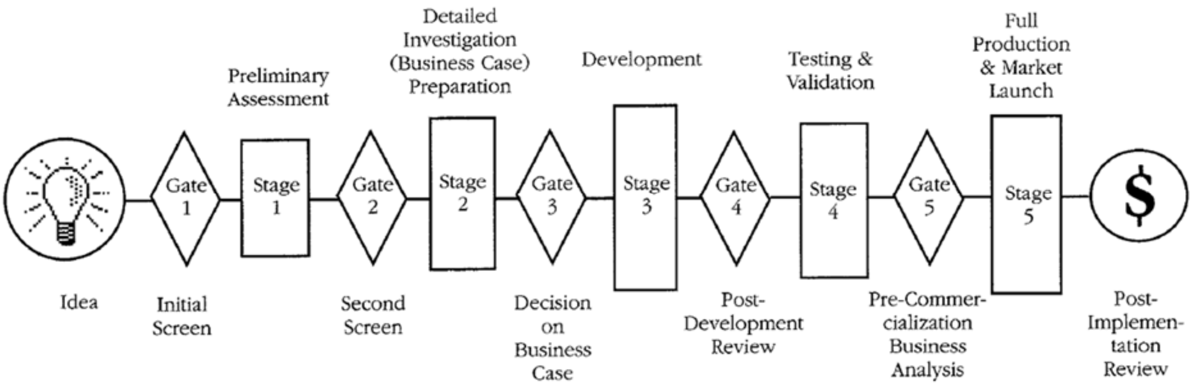



**Figure 4. Typical stage-gate system from idea to launch [Cooper 1990]**

Cooper says that more "homework" done in front-end, before the product development starts, encourages changes to occur earlier in the project than later. The challenge is that more homework means longer development times.

Kongsberg Automotive [2010] has represented a product development model that consists of gates and milestones between the tasks. This model is described in Figure 5. There are cases in which the learning cycles have been introduced with the stage-gate models. In Kongsberg Automotive learning is understood as one of the key elements in effective product development besides maintaining the knowledge and keeping it available for the use. Results of knowledge capturing consists of design parameters and relations between them. The claim is that by modelling the design parameters and the relations in which these paremeters meet, learning and the quality of decision making improves because it can be seen how the different parameters affect the other relations.

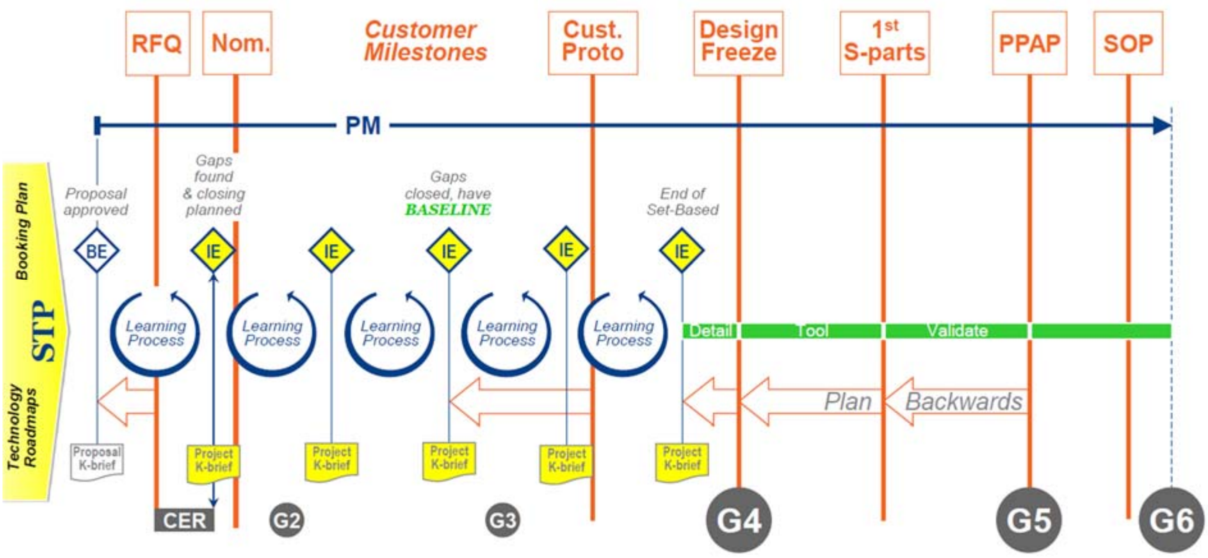



**Figure 5. An example of gate and milestone based product development model in car industry [Kongsberg Automotive 2010]**

In research related to project steering methods in software development it has been found that lean and agile models are needed in supplementing of the stage-gate system models. Jedlitschka et al. [2005] have done a case study in automotive industry called PROFES (PROduct Focused improvement of Embedded Software processes) which concentrated in the software development of the electrical control units and their integration in the car functions. In this research it has been said that agile methods are coming from the new business environments to the traditional industry like automotive. This case study focuses on the IT software development in the car. There is a very little relevant research on agile project methods used in "hardware" industry or the whole car projects.

### 4.2 Modelling of product process from the information perspective

There are research which claims that one should not concentrate on the control of the information but on the creation process of the information. Koskela [2000] represents product development and production in his theories as a flow. He notes that development as a flow process includes four stages at which information can be: transformation, waiting, moving and inspection. Only transformation is proper design work from these. Other stages can be understood as a waste that should be eliminated. A part of transformation, as rework, added work or uncertainty, is also waste. The rework will be done usually when issues are made with inadequate or unstable information. When design flows have been analyzed, it has been typically found out that the amount of the transformation is very little. So the improvement of design means that the waste should be eliminated. This enables reduction of the design time according to Koskela.

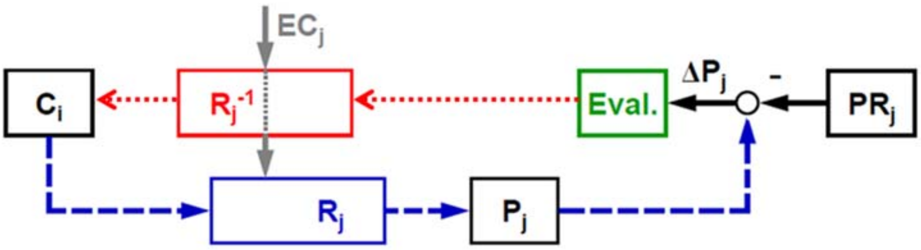
Fujimoto [2007] discusses about competence capability building in the car industry. According to Fujimoto, the product development is the creation of design information and production is the transfer of this information to the products. The role of the customer can be understood as a consumer of the design information and feedback giver to the developing of new products that is actually creating of new design information. The modelling of the creation and the transfer of information enables the manufacturer to see the value generating activities of the product. In the modelling of the information flow attention has to be paid to the four areas: where the information arises, where it is used, where it accumulates and what is the path of the information to the final product. Fujimoto explains that the ideal product process in Toyota is a flow in which the knowledge takes its form in metal, plastic, rubber and glass creating a car that can be regarded best possible within the limits of understanding. In the developing of this kind of a product process, the leading principles are found also from the research of Koskela. The flow of the process must be known and the attention has to be concentrated on its fluency and validity. If the creation process of the meta models of the information is included in the product process, a system which offers flexibility to the changes required by the business environment will be reached. [Fujimoto 2007], [Koskela 2000].

### 4.3 Research in analysing the completeness of design elements

Weber and Deubel [2003] have done research in modelling of product and product development processes. Starting point in this research is hierarchical tree structure of the parts and sub-assemblies and characteristics of those. In many cases there exist dependencies between different characteristics. In addition to the characteristics, the wanted properties of the product have a central role in the modelling of the product development process in the model. Between the characteristics of the product and desired properties there is a relation which can be approached from two directions:

- Analysis (dash line in Figure 6): the issues which describe the properties are estimated from known/given characteristics of the product.
- Synthesis (dot line in Figure 6): the characteristics of the product are determined from given product property requirements.

The starting point in Property-Driven Development depends on the case. There are several factors which affect this, such as the fact whether the attempt is to develop a totally new product or is it possible only to improve the old product. Regardless of the starting point, however, the development work is usually done by iterating the desired issue by comparing the work with the objective. In the design cycle proposed by Weber & Deubel, the guiding element is difference between properties set by requirements and properties that proposed design solution has. According to analogies by Weber & Deubel this difference is called deviation between as-is and required properties or current “error”.




Analogies:

| | |
|---|---|
| Required properties, Soll-properties ($PR_j$) | Reference value |
| As-is-properties, Ist-properties ($P_j$) | Output & feedback value |
| Deviations between as-is- and required properties ($\Delta P_j$) | Current "error" |
| Characteristics ($C_i$) | Input values |
| External conditions ($EC_j$) | Disturbances (!!) |
| Synthesis methods/tools ($R_j^{-1}$) | "Actuators" |
| Analysis methods/tools ($R_j$) | "Sensors" |
| Overall evaluation of current deviations ("Eval.") | "Control unit" |

**Figure 6. Cycles of analysis and synthesis in Property-Driven Development [Weber and Deubel 2003]**

### 4.4 Summary of the literature section

Literature review of stage-gate models shows that both large car manufacturers and smaller part suppliers use the stage-gate models in the car industry. Fundamentals of these models have not changed radically. These models usually serve as tools for management of the company. There are signs of the need of more agile methods to be used with stage-gate models also in the car industry but the availability of examples is scarce. Literature review of stage-gate models does not solve the research problem discussed in Chapter 3 alone and something else is needed. There is evidence that connecting issues related to learning with stage-gate models reduces the uncertainty. To be more precise, making the knowledge of activities that happens between the gates explicit is more beneficial and interesting.

Other approaches which could support or substitute the stage-gate thinking exists. Understanding the design as a flow of information was studied. These ideas support the challenges in making the information and its path visible (when and where the information is used). References that were studied, [Fujimoto 2007] and [Koskela 2000], do not offer "plug and play" kind of tools though.

The knowledge of the readiness of information element was also one problem in the case to be studied. An approach for the estimating of the completeness level of design elements was found. This model bases on observing the difference between the information element "under construction" and the objective. The findings from the literature were taken into consideration when the proposition for the research problem was made. This proposition is discussed in the next chapter.

## 5. Proposition for modelling and analysing of information flow

This chapter represents an approach to modelling of the information flow in product development. In this chapter it is also discussed how it could be ensured that the modelled flow includes all the needed information to realize the design intent and what features should the information system consist of to support this kind of idea.

### 5.1 Design as a flow

Based on the literature review and workshop discussions in the company a proposition to answer the research problem context was made. Concept map in Figure 7 highlights the key concepts in our topic.

This framework consists of two main areas: modelling of the information flow (dark grey elements in Figure 7) and definition of the information system concept that would facilitate estimating the maturity of the information elements (light grey elements in Figure 7).

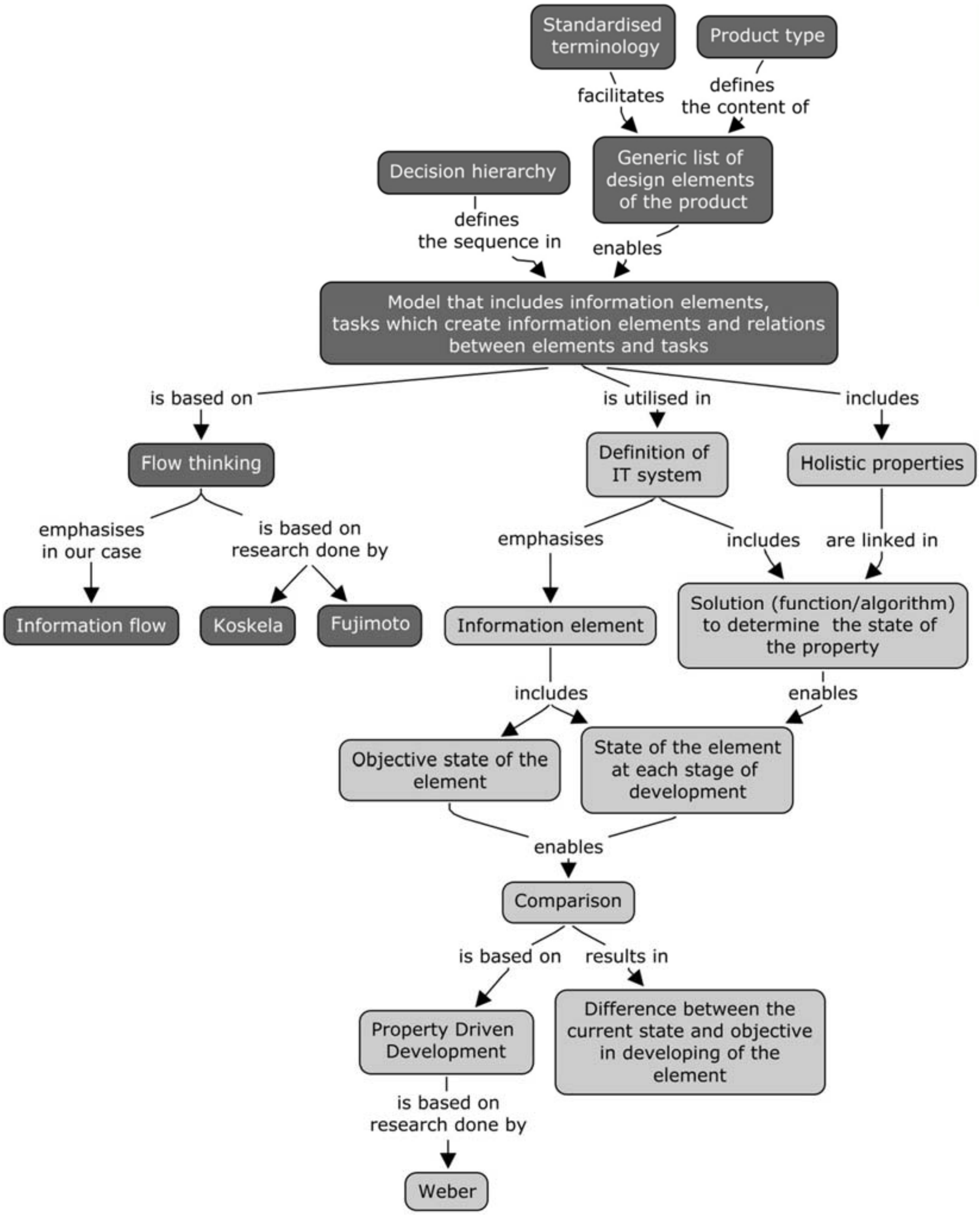



**Figure 7. The framework in the modelling of the information flow (dark grey elements) and analysing the information completeness (light grey elements)**

In Chapter 3 it was discussed that the stage-gate product development processes are common in the car industry. Tracing of the information elements is possible for example when the element is validated in a certain gate. In the case it was found out that the challenge is that the gate models do not usually pay attention to the relations between different elements. Thus stage-gate models serve well as a management tool but something else is needed if a more comprehensive view on the design flow is wanted.

The main contents in modelling of the information flow are: information elements, tasks that create information elements and relations between the tasks and elements. A draft of the information flow model was done in the workshops held in the company. Focus was in the information elements that the engineering bill of materials consists of. Our proposal of the information flow model resembles the decision tree and from the model it could be seen how the information is developed; e.g. what elements participate in developing of some other information element. The model like this facilitates dividing the product process to independent modules because modelled relations make it possible to evaluate realization of certain subareas independently when interfaces are known.

### 5.2 Information systems that support the analysing of the information completeness

If the relations between information elements and tasks are not taken into consideration, the information system in this kind of environment serves merely as a "checklist" of the product. Properties the product should have can be traced from the system but the relations between the separate information fields are not explicit.

The commercially available information technology applications offer more or less fixed data structures (key fields) for storing of information. The fixed structures are manageable if the information flow thinking is represented in the data structure of the information system. Relations between the information elements should be taken better into consideration in information systems.

We propose that case specific measuring agents could be used in analyzing the information completeness. These agents would be based on algorithms or functions that could be used in analyzing of the state of separate information elements. This would require that the most essential content of the information elements would be described using holistic properties. Agents could for instance monitor the weight or dimensions of the part against requirements. This kind of system would improve managing of the development process by collecting and visualising the current state against requirements without need for separate inspection work done by manually.

## 6. Discussion

In this paper an attempt to describe the relation between understanding the design as a flow of information and analyzing the maturity of information was represented. Information flow model according to principles of [Fujimoto 2007] and [Koskela 2000] makes the design path of the elements visible. From this kind of model it is seen that what needs to be done before advancing further in product process and where the information is used and needed. Thus the information flow model can be utilized in the estimating of the design intent. The agent based system for the automatic collecting and organizing of the information would change the present modelling way of the information flow. Estimating of the feasibility of this kind of system needs more detailed analysis of the information technology.

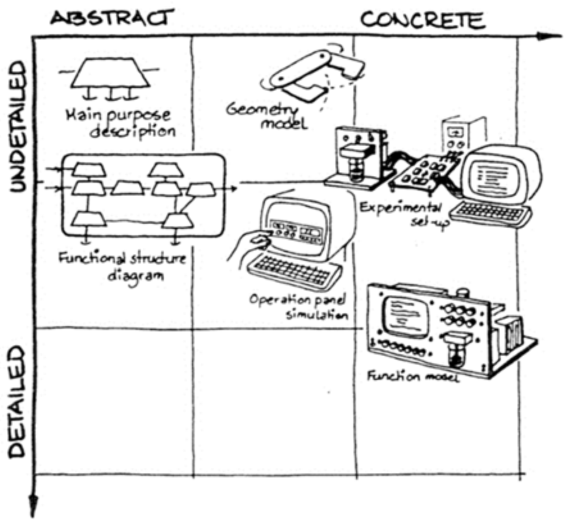



**Figure 8. Analysing the maturity of information in the Theory of domains [Andreasen 1994]**

Other approaches instead of [Weber and Deubel 2003] which focuses on information maturity exists in design theory context. For instance in the Theory of domains [Andreasen 1994], information maturity is related on the progress of designing. This is illustrated in Figure 8. The challenge in the model is that the maturity of documents does not necessarily reveal the maturity of designing. For example a 3D CAD model is always very detailed but the model does not necessarily fulfil the requirements. Thus the Theory of domains cannot be used as it is because the design intention cannot be seen from the completeness of documentation. The approach of [Weber and Deubel 2003] was chosen to our case because it addresses also the requirements.

## 7. Conclusions

Research question of the paper was how to analyse the information completeness in the product process. Answer to this question is following: Starting point in analysing the information completeness in our approach is to model the development as a information flow that includes individual information elements, tasks which are needed in creating the elements and relations between the elements and the tasks. Modelling of information flow as described above was tested in the case company. The level of detail is critical from the resource point of view when doing the information flow model. This was outlined of this paper. The continuity of the flow supports the thought of the information completeness. This means that after modelling the information flow, attention has to be paid to the fact that the information cannot neither disappear (the relations have to exist to the later tasks) nor appear out of the blue (preceding tasks must be known). If there exist elements which do not lead to any further elements, the importance of the element in the product process can be questioned. After the information flow is modelled, next step in our concept would be in linking the model with the measuring agent system. The need for research is evident in this measuring algorithm context. Thus only concept of this step was discussed. One important prerequisite/limitation for this kind of analyzing concept of information maturity is that each information element must be possible to be described using properties that the monitoring agent algorithms support.

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