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A METHODOLOGY FOR RATIONALISING PAST DESIGNS FOR RE-USE

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Abstract

Reuse is endemic in the design process. Companies recognise the concept of reuse, but few have structures for managing and taking advantage of reuse. Correspondingly, little work has been done to develop formal or semi-formal models for reuse, and consequently there are few tools which support reuse. From a survey of reuse in industry it was significant that few companies had any formal processes in place to organise designs in terms of improving the benefits from reuse, and many had a limited vision of reuse of components or assemblies [1].

1. Introduction

A basic problem with design reuse in engineering practice is the apparent lack of any formal guidelines or approach to help encourage its application and thereby allow designers to effectively benefit from previous domain knowledge. Although simple approaches to reuse can be taken, the volume of data involved, the complexity of interaction of relationships implicit in data, the "local" nature of reuse information, and the need to make reuse experience widely available in a design organisation all lead to the provision of supporting methodologies, techniques and tools.

Given this situation, the first engineering design reuse model was developed in an attempt to start to formalise design reuse [2]. The model consists of processes: design by reuse, domain exploration and design for reuse, and six knowledge-related components: design requirements, sources of domain knowledge, reuse library, domain model, evolved design model and completed design model. The work outlined in the paper would compliment the process model by presenting a methodology to rationalise past designs for their effective reuse. Such rationalisations provide a basis upon which to efficiently retrieve specific cases for reuse and present a means upon which to generalise, learn and reuse past experiential knowledge.

The methodology was developed from combining research in design reuse and satisfying the needs of industry. Thus, the usability and utility of the methodology was measured within an industrial context. The successful accomplishment of rationalising the company's past designs indicates that the concept of the methodology is promising. During evaluation the weaknesses and strengths of the approach and possible areas for future development were identified.

This paper presents the main steps in a methodology developed to rationalise past designs for a particular privately owned company, producing candle filters and demisters for pollution control, of 35 employees with a history spanning more than 140 years. It does this by giving some an outline of some of the main work within the field relating to the companies requirements. The overall methodology is then presented and the individual steps described. It is concluded that while the methodology provides a starting base for rationalising (structuring) past designs there is considerable work required to take into account the full life-cycle issues when structuring past designs.

2. The Design Re-use Process Model

The design process can be defined as a series of tasks and decisions utilising scientific principles, technical information and creativity in order to produce a solution to meet an actual or perceived need. It requires different information at various stages of its process. The difficulty associated with making decisions during the design process is dependant on the knowledge and choices available to the designer. A feature of design decision making is the reuse of previous design experiences. Such experience holds a wealth of explicit and implicit knowledge and can be interpreted differently depending upon the needs of the designer(s). Thus, experienced designers will generally find certain decisions easier to make than novice or inexperienced designers as they can draw on knowledge gained from previous experiences [3].

Although the concept of design reuse is accepted as a valid approach to design, little attempt has been made to formalise the elements that constitutes design re-use. The few approaches formalising design re-use, e.g. 'Concept Re-use Approach for Engineering Design Problem Solving' [4], tend to be prescriptive, detailing procedures and functions that have to be carried out in order to re-use designs. Such prescriptive methods fail to identify the underlying processes of design re-use and tend to relate to a specific system or method of tackling re-use rather than re-use itself. It would seem that the only current model encompassing design re-use is 'The Design Re-use Process Model' [2].

The 'Design Re-use Process Model' (Figure 1) was influenced by processes from the domain of software engineering re-use. The model describes the design re-use process using the interactions between six knowledge resources and three main processes.

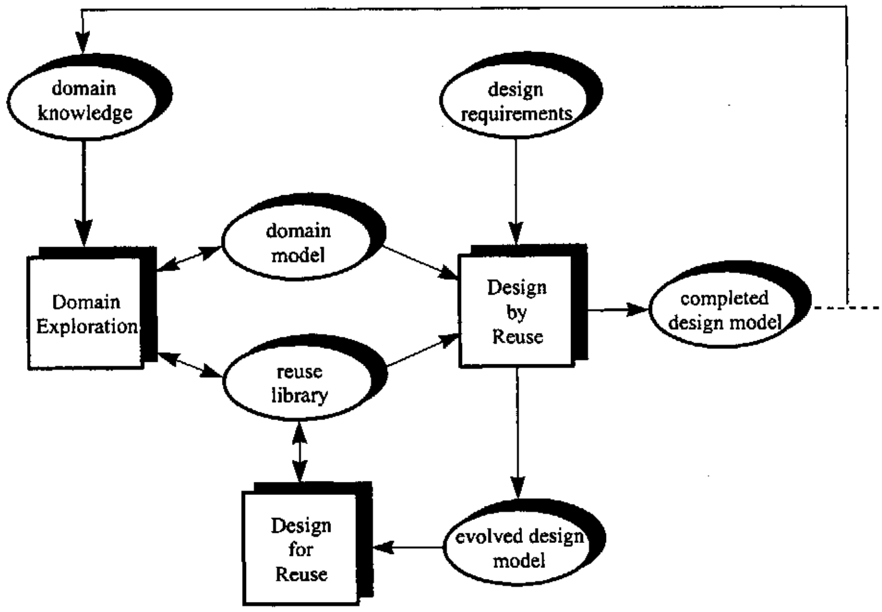

Figure 1 - Design Re-use Model [2]

The knowledge resources are:

The *Domain Knowledge* - sources of knowledge concerning past designs or artefacts.

A *Domain Model* - a designers conceptualisation of a design domain, applicable to the current design problem.

A *Re-use Library* - an organised storage for holding reusable knowledge.

Design Requirements - a statement of a design need.

An *Evolved Design Model* - a description of an incomplete, proposed or final design, at any level of abstraction.

Completed Design Model - a statement detailing the complete definition of a new design.

and the processes are described as:

Design by Re-use - the re-use of previously acquired concepts in a new design situation. Design by Re-use can only occur if reusable resources are available through for example 'Domain Exploration' and 'Design for Re-use'.

Design for Re-use - The identification and extraction of possible reusable knowledge fragments and the enhancement of their knowledge content, including recording developed design alternatives, modifications and associated reasoning behind design decisions. This process is carried out during design itself.

Domain Exploration - the examination of a design domain from which reusable fragments of knowledge can be identified, rationalised, extracted, stored and subsequently used to develop new designs.

In essence the Design Re-use Process Model is a cyclic process where knowledge is abstracted from a new design and used to build or enhance the domain model, through domain exploration, and add to the knowledge within the re-use library. These two knowledge components, the domain model and re-use library, are then used during the process of 'design by re-use', consequently resulting in: (i) a completed design model and (ii) knowledge relating to the product, process and rationale, which in turn are fed back into the re-use process to aid future design.

Design by re-use can occur with various types of knowledge such as plans, schema's, episodes and general principals. All require an adequate store of knowledge to be effective. Although the process of 'design for re-use' contributes to these knowledge resources, 'domain exploration' is an essential element to providing comprehensive knowledge stores. The methodology presented in this paper is a tool for domain exploration in order to rationalise (structure) past designs for the domain model or re-use library.

3. Product structuring

For the company in question product structuring could be considered to address three different but related areas: manufacturing and assembly, product familiarity and variety and the product design process. For each of these areas, researchers have suggested different techniques upon how to design the product so that it suits the product structure requirements for the particular area's viewpoint.

Techniques related to manufacturing and assembly are primarily part standardisation and parts reduction [5] and modular or integral product design [5, 6]. Furthermore it has been argued that more efficient production should be achieved i.e. less variety, in the manufacturing process [5]. This goal of maximum commonality between product variants with respect to manufacturing is closely related to the area of product familiarity.

Work related to product families suggest carefully reviewing the offered product range as well as the customer base and their requirements [5, 7, 8]. The amount of product variants can be reduced as unnecessary variants might be identified and avoided [8, 9]. Remaining variants can be optimised if they are common in their manufacturing process - i.e. late introduction of some specific feature [5], to make the products familiar in as many life phases as possible [10].

Related to the overall design process, focus has been upon the management of data during the design process. The essential question being addressed is what data must be captured to gain the highest benefit [11] from the structure. Frameworks which have been proposed by researchers aim in defining the relevant data, their relations and constraints [12, 13].

The main areas considered in product structuring are summarised in

Figure 2. The given recommendations are not of a general nature, as they were formulated for certain problem area. This reflects the fact that, for different problems different product structures have to be developed. It is quite important to note that most of the given recommendations focus on the creation of a product structure for a new design. As this thesis focuses on the development of a methodology to structure exiting product knowledge, some of the above points might have to be altered and tailored slightly.

manufacturing/assembly
- modular and/or integral design
- part and product standardisation
- minimum variation in production

product familiarity/variety
- review customer base
- identify needed/unneeded variation and importance of certain variants
- identify (possible) product familiarity

product structure to sipper design
- identify and categorise elements
- identify relation between elements
- present constraints
- present configuration solutions
- reduce/simplify amount of information

Figure 2: Main areas in product structuring

4. Overall approach of developing the methodology

The purpose of developing the structure was to provide an overview and some rationalisation of the company's products. The development of the structures, however, gave a fundamental and unbiased introduction to the problems and difficulties when creating product structures. Hence, it was possible to draw some general conclusions for a methodology.

There were no existing methodologies that could be relied upon to rationalise (structure) the companies past designs. Consequently, the general problem-solving procedure developed by Pahl and Beitz (Figure 3) was used as a starting basis.

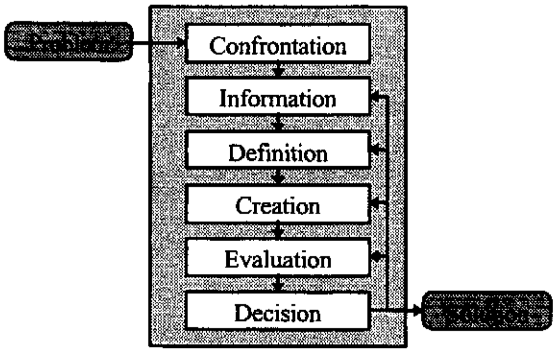

Figure 3: General problem-solving procedure [14]

The essential part of problem solving involves a step by step of analysis and synthesis [14]. As suggested by [15] a product structuring methodology could be based on such a principle. The procedure consists of several steps. After each step it may become necessary to upgrade or improve the results of the last i.e. to repeat it by taking the newly gained information into account. Hence, the process is of an iterative nature. After the initial confrontation of the problem with what is already known, more information is needed to clarify the problem. The amount of the needed additional information is dependent on the knowledge, expertise and experience the person has from the particular problem area. However, in any case the detailed information collected during the second step will clarify and illustrate the problem in more detail. In the third step (i.e. definition) the crux of the task [14] is defined. This describes the essential problem at an abstract level. From this the requirements, objectives and main constraints are formalised. A solution is created which then has to be evaluated and checked. As a final step a decision is made, whether the evolved solution will meet the initial requirements and objectives. If "yes" the problem is solved, if the answer is "no" then several of the previous steps have to be repeated until the developed solution satisfies the requirements.

Based on the gathered information the product structures were created. To do so, it had to be decided, how the information was to be structured i.e. the structure type had to be identified. It was decided to use a part breakdown structure, as it was believed that this would be the most suitable structure to show the configuration and specification of the products.

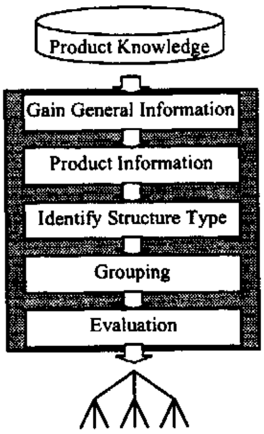

Figure 4: Product structuring steps

The creation of the product structures were done in three different steps. Firstly data was grouped according to the different product types. Secondly these groups were broken down further. Finally, the structure was evaluated mainly by examining how well the contained information matched the actual situation.

The overall process followed an underlying sequential procedure which is shown in Figure 4. This procedure gives some key points for a formal demonstration for a product structure methodology.

5. Objectives of the methodology

To ensure consistency of past work and meaningful structures to the company a number of objectives were specified prior to carrying out the rationalisation process.

The approach focussed on two main aspects: on the one hand the user should be guided to find the most appropriate product structure for a given problem. On the other hand the products might have to be altered to suit the task (i.e. to fit as good as possible into the structure). Hence, the methodology should identify these areas and give suitable recommendation (e.g. variety reduction, parts standardisation).

The methodology should consist of different steps in a chronologically sequence. The above described problem solving procedure will serve as a guideline.

The approach should build upon existing formalisms such at that suggested by [12, 16]. Their formalisms structure the product information into two distinct but dependent structures. A Product Family Tree (PFT) and a Product Breakdown Structure (PBS). Such structures are useful for several reasons. Firstly, they are fairly comprehensive as most work in the area use similar relations. Further, these structure types (especially the Part Breakdown Structure) are in one form or another familiar to most companies [17] and thirdly only fundamental work has been done in the development of other data storing concepts [18].

The complexity and dynamic character of product structures will make computer support necessary when developing and using the structures i.e. the derived product structure have to be computer based. The developed methodology can be seen as a prototype which will support the identification and main problems when developing product structures. The methodology should also be easy to use.

The above objectives served as a base for the evaluation of the evolved methodology and can be summarised as:

- give a structured approach in product structuring
- identification of elements, relations and constraints restricted to PBS and PFT
- identify areas of product improvement (e.g. variety reduction, standardisation)
- easy to use and understand
- suitable for (later) computer system
- assist and help to identify problem areas

6. The Methodology

The methodology consists of ten steps in an overall sequence (see Figure 5). The overall sequence of the steps is kept fairly general. Therefore the methodology can be utilised for different product structuring problems, as it is believed that the overall procedure is independent from the actual domain.

Every step in turn is broken down into several sub-steps which give suggestions how to proceed in the subsequent steps. This gives more individual support to the users' problem. For the sub-steps no sequence is suggested as the user has to decide which of these are most suitable for the current problem.

As for every problem solving process, several steps might have to be repeated if the results are unsatisfactory i.e. the structuring process is of an iterative nature. The results of each step should be evaluated before moving on to the next. This serves as a check on progress towards the objective. These intermediate evaluations are not shown explicitly in the figure but are indicated by the arrows on the right hand side of the figure.

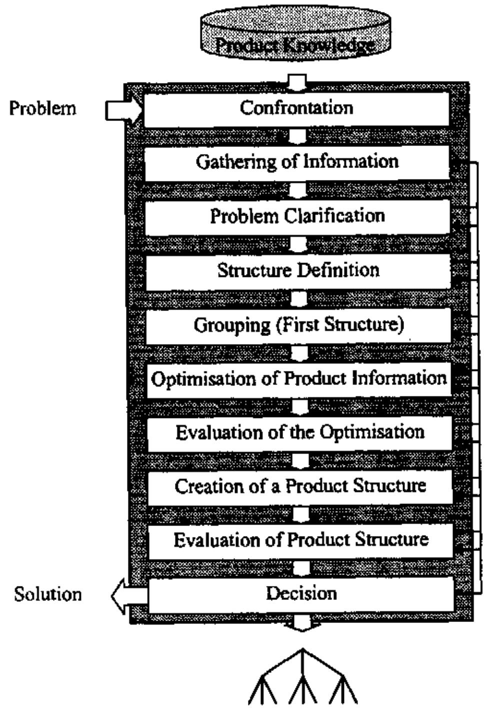

Figure 5: Product Structure Methodology

6.1 First Step: Confrontation

At the beginning of every problem solving task stands the confrontation with the problem (Figure 6). This activity will give an initial idea of the type, extent and character of the problem. Furthermore it can be clarified if the problem area is familiar and as a result it may be possible to estimate how much knowledge is already known and thus, what and how much additional information is needed. Hence, the time for gathering additional knowledge can be estimated. Furthermore information can be obtained which might be important for the development process.

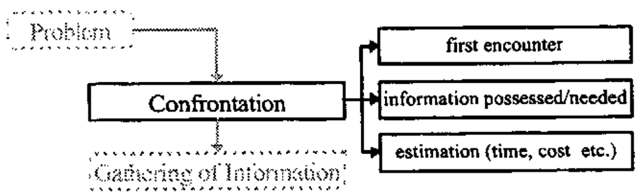

Figure 6: Confrontation

In reality, this step is usually not carried out separately, as it is closely connected with the information gathering step (see section 6.2). However, for the methodology these two steps are distinguished as the problem clarification will be dependent on the results of the first description of the problem (i.e. this step).

6.2 Second Step: Gathering Information

The second step of the methodology is to gather all the information in order to obtain a good and deep understanding of the company and its products. As mentioned above the needed amount of information and knowledge will be dependent on the quantity of the already held knowledge. However, the collection of the product knowledge is the most important, crucial and time consuming activity as it involves a lot of examination and research as well as a series of discussions through out the life-phases, such as with sales, production and maintenance engineers and industrial designers [12].

The quality of the accumulated knowledge will directly influence the quality of the developed structure as insufficient, wrong or incomplete information will have the effect that the product structure will not be as good as required i.e. the developed structure will only be as good as the collected information. However, information gathering should not only be restricted to the product itself but should also cover information about the different users in the company, the company itself and the time critical knowledge.

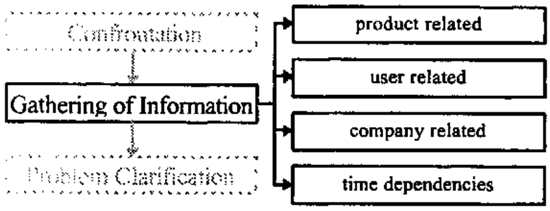

Figure 7: Gathering of information

Which of the above aspects of information gathering become especially important for a certain case is dependent on the respective problem of the company. The main objective of this step is to obtain all or as much information as possible to provide an as wide, complete and fundamental as possible collection of data. It is the quantity of information which is important at this stage not its quality. A wide information base will increase the likelihood to find a correct structure (in terms of its functionality) and good structure (in terms of product life aspects) [19]. However, no conclusions, alterations or decisions concerning the context/amount of information should be made at this stage.

6.3 Third Step: Problem Information and Clarification

To be able to find the optimum product structure the current problem (need for the product structure) of the company must be understood and defined as fully and clearly as possible. As a consequence of this step the requirements of the company have to be identified and described. The description of the requirements should be done on an abstract level as not to prejudge and thus limit the search for solutions. However, it is believed that this can only be done when detailed knowledge about the problem area is already obtained, therefore this step comes after information gathering.

As can be seen in Figure 8 problem clarification includes a number of different aspects. It is a key activity when developing a product structure as it is this step the general structure type will be determined, which will influence the next steps.

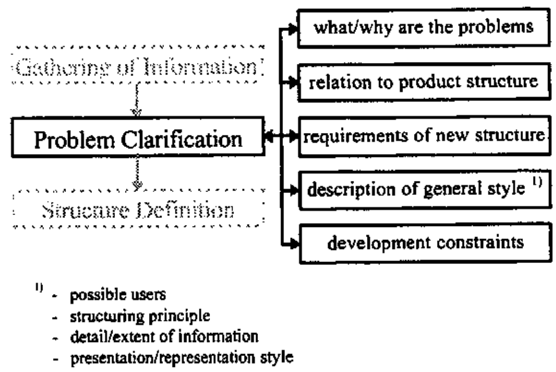

Figure 8: Problem information and clarification

Focus should be upon the (main) requirements of the company. What are they and what are the reasons for these requirements or shortcomings? An important point is to estimate if, or how, the identified problems are related to product structuring i.e. how can a product structure contribute to overcome the problems. The examination of these difficulties will clarify the actual task (i.e. developing a product structure) and it becomes possible to formalise the requirements of the new structure. As the requirements will fix the style of the later structure, the structuring characteristics can also be identified i.e. if according to the function or assembly sequence of the products or according to their features, behaviour, distribution, customer or manufacturing requirements.

As shown in Figure 8 it is during this step that the (main) users of the structure will be identified along with their type and amount of information required, their needed level of abstraction or detail of the information, as well as the required presentation and representation of the information.

Specific requirements will differ and it might be helpful to list and group them according to their individual importance. Such a list would be similar to a requirement list [14] and will clarify upon which of the requirements to concentrate when developing the structure, as some of them might be contradictory and hence can not be met equally. If or to what extent which of the requirements can be accomplished is dependent on the possibilities of the development process e.g. time, financial or other limitations.

6.4 Fourth Step: Structure Definition

The clarification of the problem will lead to the fourth step of the methodology in which the structure will be defined. As shown in Figure 9 this step includes the definition of the objectives, the formulation of the main goals and the proposed benefits.

The definition of the objective is an important step as it determines the product structure - i.e. it defines its characteristics.

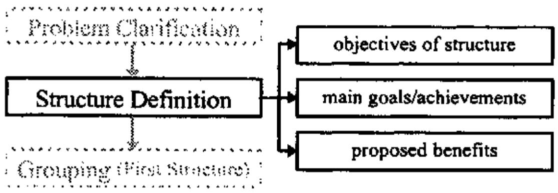

Figure 9: Structure definition

Objectives are mainly derived from the customer requirements by taking the constraints into account i.e. the development limitations. The objectives should define the main goals and expected benefits of the structure i.e. they are a description of the proposed structure and its characteristics.

The main purpose of the objectives is to be able to evaluate and asses the final structure, as evaluation criteria can be derived directly from the objectives [14]. The solution (i.e. structure) is evaluated by measuring if/how the defined objectives have been achieved. This in turn serves as a base for a decision whether the derived solution can be accepted.

6.5 Fifth Step: Grouping (First Structure)

As shown in Figure 10 the purpose of this step is twofold: firstly the relevant information which has to be stored in the structure is identified; secondly the relevant information is brought into a first arrangement. As the arrangement of the information will be dependent on the type of information (and vice versa), both activities are carried out in one step. Which of the gathered information (see section 6.2) will be relevant for the product structure is determined by its purpose.

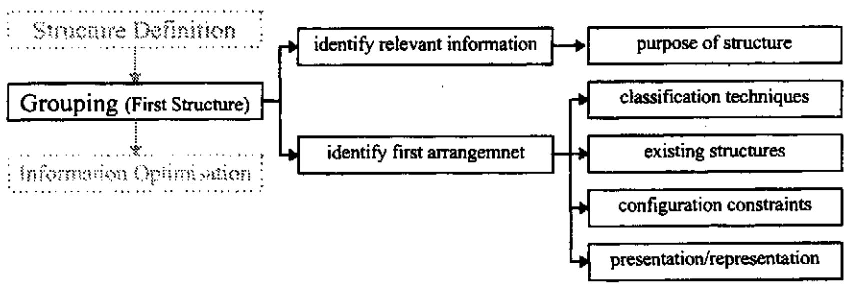

Figure 10: Grouping (first structure)

In this step groups of information are identified which differ significantly in their attributes and those which are similar. These groups give a first arrangement of the information. Grouping can be done by several means such as classification techniques or clustering. Other possibilities for grouping could be to use existing product structures as a guideline, but it should be noted that these structures could have been developed for use in specific domains which may not have considered more corporate aspects [9]. Furthermore, the physical architecture of the product can be considered e.g. the grouping could be done according to sub-assemblies, product groups or other characteristics of the products.

Which technique to use depends upon their individual suitabilit. For example if the attributes are expressed in concrete quantitative (numbers) or qualitative (verbal) terms.

Related to the arrangement of the groups, general restrictions and constraints related to the product (and its structure) should be identified e.g impossible arrangements of parts/functions. According to O'Donnell et al [9] the constraints knowledge comes either from the designer who is in charge of the product design or the user who provides particular requirements which may reduce the different choices.

This fifth step can be seen as a first reflection of the requirements and objectives of the structure which were formalised in the previous steps. Note that the grouping/classification considers attributes of the collected information and their similarity and differences but not necessarily defining explicit relations between them, as it is believed that at this step it is satisfactory to only distinguish between groups of knowledge.

6.6 Sixth Step: Information Optimisation

The purpose of this step is to reduce the complexity and amount of product information by suggesting possibilities to optimise the product design. In Figure 11 five different techniques to do so are shown. They all focus on optimisation of the product design, as the main objective of information optimisation is to increase the efficiency of the product's development and manufacturing.

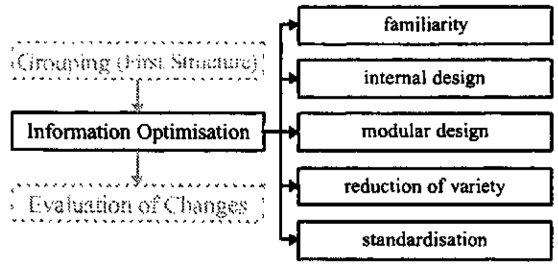

Figure 11: Information optimisation

A starting point is provided by the different groups which were defined in the fifth step. These groups give a first basis to examine the product design in more detail. An examination of their differences, similarities and dependencies will give a suggestion on how the design can be altered in order to reduce the complexity and amount of information. The goal is to identify commonality between and within the groups. The groups have to be compared in terms of their design to identify similar and/or different designs of the respective groups. In addition, it has to be investigated how a group is changing its character or design for different product variants, while considering the whole product i.e. its different options, variants, characteristics. Another source which can be consulted are customer complaints or any other kind of feed-back. This might help to identify unnecessary variants or unneeded features so that the design can be optimised and hence simplified (in relation to the product structure).

Based on this comparison, similarities and possible areas of improvement can be identified. In the following, for each of the five different aspects shown in Figure 11, some suggestions are made on how to identify or implement the idea. Which of these are suitable is dependent on the case under question, therefore the different aspects might have to be investigated closer.

Familiarity
Product families offer a wide range of product variants by choosing from a fixed set of sub-units (modules), parts or elements. By this, many different variants can be produced without loosing the benefit of mass production, as most of the modules will be common between the variants. Thus, a part of this aspect of step six is to investigate how the identified groups can be made common. This is particularly relevant to groups/products which are similar, as it is quite likely that they share a common architecture, so that only specific features have to be added for the respective variant. Another possibility would be to use many parts independent from the group/product i.e. part standardisation (see below).

Integral Design
The objective is to reduce the number of parts by embodying many functions in one part. This will increase the complexity of the part but simplify or even avoid assembly operations. Integral design is difficult to achieve as the development of such a design is very costly and time consuming and therefore only suitable for mass produced products.

Modularity

Modularity is seen as the opposite of standardisation [5]. Functions are allocated clearly to the parts (i.e. module) so that a different overall performance (i.e. function) of a product can be established by selecting different modules. The different modules have to share common interfaces in order to be able to combine them.

It should be investigated if such modules already exist. A starting point could be sub-assemblies and sub-units which may can be made common for different products. Modularity is closely related to product familiarity as they often use modules to realise instances of variants. In terms of the product design it should be investigated how the functions are distributed over the parts. The goal would be that one group realises one (or more) functions.

Variant/Part Reduction

The amount of product variants is another important aspect in this context. Product variants are needed to satisfy specific customer needs [9]. A main problem at present is that the number of offered variants has grown uncontrollably in the past years and companies have accumulated a high amount of data [6].

It should be questioned if all the variants really must be offered [8]. For some the batch sizes may have decreased [9], other variants might lead to problems in engineering and/or production. Hence, it might be possible to identify unnecessary variants [9]. A starting point could be to investigate past orders, customer feed-back etc. to limit the variation.

Variation reduction can also be seen in the context of part diversity. Diversity means that for one function several solutions exits i.e. many different parts are used for the design which all serve the same purpose. The goal would be to identify common parts i.e. standardisation and/or a common physical product structure i.e. modularity. Other possibilities are to join different parts to one unit or sub-unit i.e. integration.

Standardisation

In terms of standardisation, parts are identified which can be used for more than one product design. It should be examined and justified why different part types (or sub-units) are needed. The goal is to increase the number of parts which are shared by different products.

6.7 Seventh Step: Evaluation of Changes

The alterations which were done in the last step will have consequences for various areas of the company in terms of the manufacturing and/or assembly process, work-flow, organisation etc. However, the consequences cannot be fully foreseen or overlooked by the developer of the structure. The different aspects shown in Figure 12are only a suggestion of what to consider in this step. As a consequence, decisions concerning the product design have to be done very carefully and in a close relation to the company and their engineers, as they have the experience and knowledge how the different aspects are related to each other, and they can estimate if and/or how certain changes can be done.

The purpose of this step is to assess and evaluate the proposed changes in terms of their feasibility and realisation i.e. it has to be ensured that the suggested changes are realistic and can be achieved with defensible and appropriate effort. It then has to be decided which of these changes are most promising.

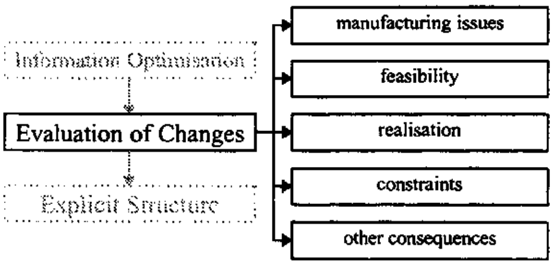

Figure 12: Evaluation of changes

6.8 Eighth Step: Creating the Product Structure

After optimisation, the structure will be formalised. In this step the final product structure is developed, bringing the above defined and optimised groups into a logical and concise arrangement. Thus, for the elements within each group, as well as between the groups, relationships have to be established (see Figure 13).

Here two different types of relationships are distinguished as examples, but of course there can be many more to suit the particular needs of the users [20]: *part_of* and *type_of* which are in turn represented by either a Product Breakdown Structure (PBS) or a Product Family Tree (PFT). This approach is taken from [12]. The two structures are interrelated with each other in a way that a node in the PBS can be broken down by a PFT and vice versa.

In this step the elements as well as their relations have to be defined i.e. it is determined which of the elements have which type of relationship. In addition the relation between different structuring trees has to be determined as well. The relations have to be defined according to the groups i.e. it has to be identified if a group is embodied by others (i.e. part_of relation) or if a group is a possible option among others (i.e. type_of relation). The link between different product structures is either established by defining the node in the tree where this tree is connected to or by annotations.

Other aspects which have to be taken into consideration are the required level of detail or abstraction i.e. to which extend has the product information to be shown. Another is how many structures are needed to capture the required information. On the one hand different structures might be needed to display all the information, on the other it might cause problems when too many structures are existing at the same time.

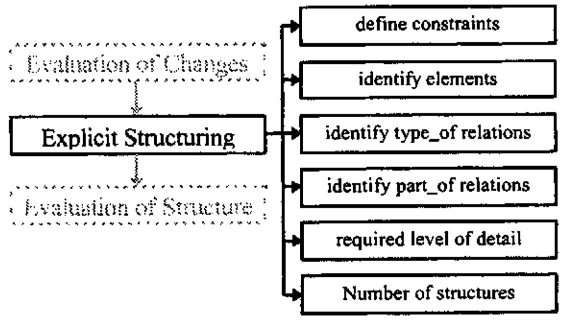

Figure 13: Explicit structure

The different elements usually have limitations concerning their combination and/or compatibility. To ensure consistency and avoid redundancy of the information these limitations have to be identified and added to the structure. Such limitations are related to the combination and compatibility of the parts e.g. only use part x together with part y, or part z is always made of metal. Hence these constraints have to be reflected in the structure so that no impossible combinations can be defined. Limitation also exist related to the dependencies between different parts. i.e. which of the par'ts attributes are dependent or determined by other parts. Hence if the attributes of an element changes all related information has to be updated as well e.g. the thickness of *part a* has to be the same as of *part b*.

In a computer based structure these links and cross-references can be written as rules or constraints, in a paper based structure they can be established by graphical connections or annotations. To define these constraints requires a very deep knowledge of the products and the company. Note that such limitations can also be originated by other aspects than design.

6.9 Ninth Step: Evaluation of the Structure

Finally the created structure has to be evaluated. As shown in Figure 14 different aspects of the structure have to be considered in this step. Evaluation provides an objective basis for the decision (see next step) whether the evolved solution is acceptable or not by measuring and determining its value, usefulness or strength as well as its weaknesses with respect to the stated objective [14].

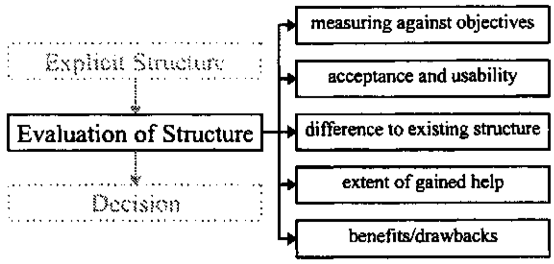

Figure 14: Final evaluation

Evaluation always involves a comparison and rating or gauging either against another solution, against an imaginary ideal solution and/or against the set of requirements. The objectives which were defined in the fourth step serve as a base from which evaluation criteria can be derived. In technical fields such criteria are mainly the user requirements but are also related to cost, performance, cost-benefit, etc. For a product structure other additional criteria might be of interest. Evaluation should be done by looking at aspects such as the level of improvement or by listing the achieved benefits and advantages when using the new structure compared to the former situation i.e. how good or bad the structure assists the user. Finally, the user could be asked to gauge the usability and acceptance of the new structure by comparing it with the former situation or, if applicable, with former structures.

6.10 Tenth Step: Decision

The decision for or against a structure is always based upon the results of the evaluation (see Figure 15). The result of the evaluation is a description and ranking of the new structure related to the chosen criteria. The evolved structure is accepted if the result meets the objectives; if the results are not satisfactory the structure has to be revised i.e. the last step(s) have to be repeated. The decision if a structure is accepted or not can be influenced by other aspects. For example, although the structure is not satisfactory, it might be accepted, as a rework or repetition of parts or the whole development process will be too costly or time consuming. A structure can also be accepted when it can be predicted that a further development will not lead to improved results, this includes that the development process may have to be stopped entirely as no solution is possible.

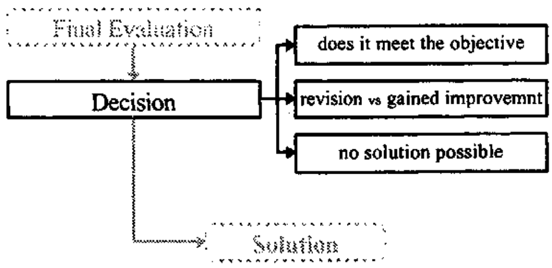

Figure 15: Decision

7. Summary

In this paper a prototype of a methodology to derive product structures was developed and discussed. A first concept of the methodology was derived adapting a trial and error approach. Past experience, researchers recommendations and a general problem solving technique were consulted for the formulation. The main characteristics and basic principles of the methodology were described.

The purpose of the methodology is to assist and guide the user when creating product structures. The methodology consists of several steps in a given iterative and chronological sequence leading the user from the initial problem through a first definition to the final product structure. Each step was described in detail i.e. the respective actions to take for each step.

The methodology has been applied and developed within industrial practice. From this it was realised that it is essential to have a thorough knowledge of the products. This includes the manufacturing and assembly processes, the possible options and former designs. In addition, knowledge about the company itself, its customers and suppliers, the working structures etc. were considered. Although some of the gathered information was not used for the structure itself it provided a background to the problems of the company and the general environment in which the structures would be used.

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