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TOOL FOR CONCEPT EVALUATION BASED ON THE PROPERTIES OF THE CONCEPT AND THE BUSINESS ENVIRONMENT

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1. Introduction

The dense pace of modern world puts great challenges to companies as they are required to bring new products and innovations to the market frequently. This on the other hand means that new concepts have to be created faster. So there is a need for a tool by which the designers get confirmation that their new concept is realisable in the current situation. The matter is checked from the compatibility of the interrelation of materials, from the feasibility of the methods to be used, and from the capabilities of the business environment. Exclusion of non-realisable concept saves the resources from an unnecessary use.

It is challenging for the small and medium-sized companies whose product development is occasional to envision situations to which attention should be paid at the development phase of a new product and its life cycle. The problem is often that the consequences of the planning and development decisions which are related to the life cycle and business environment are unclear. Result of this previously mentioned problem is a product that is not suitable in the best way for the production network and for the end user.

This research was done in cooperation with small and medium size Finnish boat industry. The case used in creation and testing of our tool was real ongoing conceptual product idea and the different aspects of the tool were verified with the designers and experts of the companies. The products of the boat industry are fairly specialised in manufacturing aspects, thus development and testing of our tool was trustworthy.

The Goal for early phase concept evaluation is to find out whether the concept at hand is “a good one”. This leads to a question, what “good” means here, thought a concept is just a prediction of what might come from the product development process. We could approach this matter by supposing, that we are talking now about good quality.

Firstly it is crucial to see if the chosen properties cohere together in the same concept. Secondly the suitability of the concept to the environment during its life cycle has to be confirmed. Products have multiple different phases and operation that they go through during their life cycle starting from the raw material all the way to recycling. One key phase form the company point of view is the using phase. There the user formulates his/her opinion about the product and thence opinion about the company. Some behaviour might get forgotten or not even considered when changing to new technology. E.g. the LED bulbs are new innovation in car head lights, but the led technology brings new problems in colder environment. The halogen bulbs generate enough heat to defrost the cover class but this behaviour doesn’t occur in the LED bulbs and an external heating is required.

Our motivation is to create a tool to visualise the feasibility of the concept in very early phase of the designing. Second important aim is to build the tool which is easy and practical to use and gives the results quickly. The tool covers the properties of the concept and business environment widely so in most cases it gives information which might have escaped from the designers' attention.
We demonstrate in this paper our view on the product concept and on those scientific grounds on which our tool is based. The theoretical background is based on viewpoints of a technical system and ideal situations in case of a product and its production. This paper is the first step in the introduction of the tool and the purpose is to present the grounds for the tool and its principles.

2. Theory basis of the research

In his article "Design for Quality and Design Methodology" Vladimir Hubka [Hubka 1992] defines what quality means in the context of Technical System (that refers to Theory of Technical Systems, see more [Hubka and Eder 1984]). Hubka refers to German industrial standard DIN 55350, which defines quality as the totality of the properties and characteristics of a product or activity that relate to its suitability to fulfil the given requirements. Thus – according to Hubka – quality is concerned with statements about the "what" and "how" of an object or process, a total judgment about a system of properties that make an object what it is, and in what ways it is different from other objects. According this Hubka concludes that quality in a Technical System is tightly linked with properties. To clarify what these properties are, Hubka presents following relationships of properties.

Table 1. Relations of the properties of technical systems according to Hubka [list revised from Hubka 1984]

Internal properties (What the designer has under direct control.)	**External properties** (Properties that the technical system carries.)
General design properties Elementary design properties Design characteristics	Functions, Effects Functionally determined properties Operational properties Manufacturing properties Distribution properties Delivery and planning properties Liquidation properties Ergonomic properties Aesthetic properties Law conformance properties Economic properties

According to the thinking of Vladimir Hubka (and DIN) the quality is suitability to fulfil the requirements on the properties listed in table 1. This includes the assumption that the requirements are:

1. Complete
2. Correct
3. Quantified (possible to quantify and variations/tolerances stated)
4. Qualified (importance of requirements must be clearly visible)
5. Formalized

Thus Hubka's [Hubka 1992] idea of quality includes two aspects: The right definition of the requirements and achieving them.
The *requirements for requirements* above are enough for analysis but they only give some hints for the synthesis. Seppo Suistoranta has discussed the topic of "a good product". In his dissertation [Suistoranta 2007] he has proposed a concept of "goodness". The concept starts from a theorem, that there exists an imaginary ideal realization for (every) technical system. In the idea of "ideal machines" Suistoranta references Altschuller and Savransky [Altschuller 2000] [Savransky 2000]. In Altschullers consideration he proposes that in technical evolution every new machine strives towards an ideal stage along its own line of development. In the end, these lines converge at the same point, which is called *the pole* (see Figure 1.). A technical system may be called an "ideal machine" when it has evolved and reached the pole. The question is when and how we know what the ideal state of the machine is.

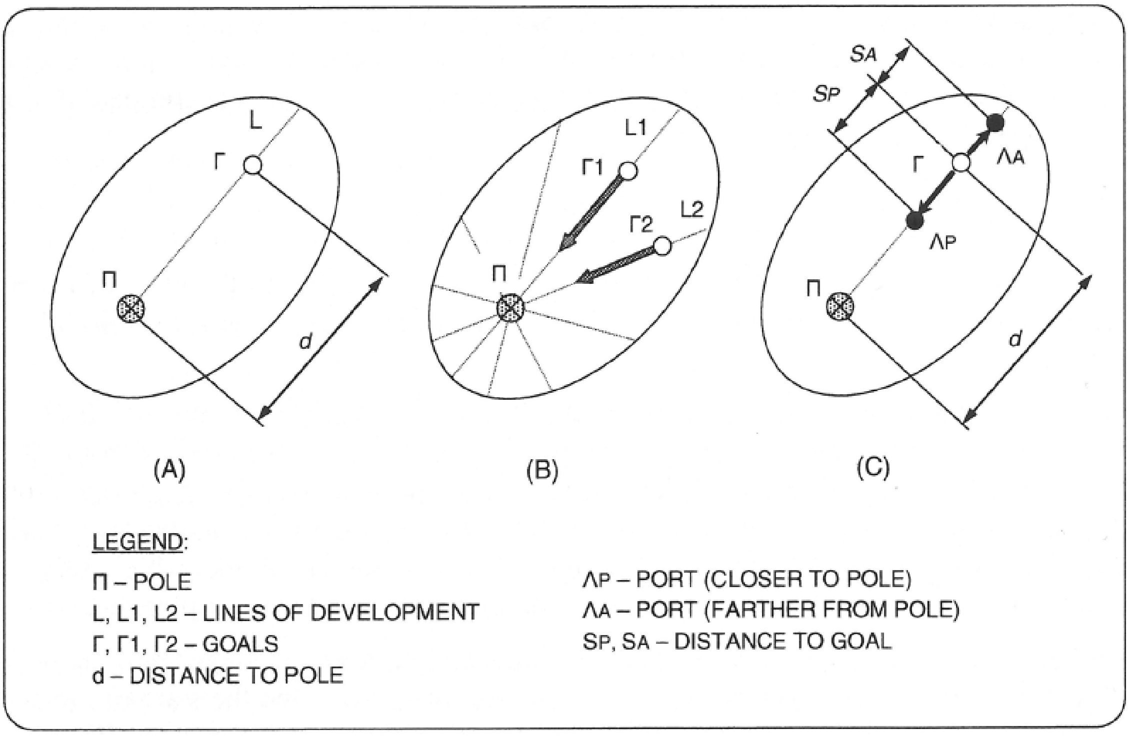

Figure 1. The evolution of machines and the ideal solution in design space "the pole" [Altschuller 2000]

The Savransky's ideas about ideality are somewhat abstract. For example the proposition that the "ideal process is actually only the process without the process itself" is very near of the goals of Bauhaus school. For example the Bauhaus evolution of designing a chair is a good example of this. In that example the ideal situation is one where the actual chair does not exist at all but it is possible to sit in "air" [Fiedler & Feierabend 2000]. These thoughts are fairly far from the real world but they are extreme examples about the ideal state of a product. The ideal state is not realisable in reality, where the concepts are always compromises of the different variables.

Suistoranta defines *the goodness of a technical* system as follows: *"The goodness of a technical system is relative to its distance to the pole – that is the point of absolute ideality"* This leads to a search of the pole! One approach in trying to define the ideality in evaluation according to the so called *seven universal virtues* proposed by Andreasen and Olesen [Andreasen & Olesen 1990]. Because these virtues have different meanings in different contexts, Suistoranta refers to Karl Popper [Popper 1978] and utilises *three-world ontology*. This theorem claims that reality divides in three different sections:

- World 1: This contains substantial physical bodies, events and processes
- World 2: This contains the human mind, states of individual consciousness and events.
- World 3: This is formed by all the things that humans create through social activities.

According this Suistoranta presents following table (Table 2) that shows the different elements of the universal virtues in these three worlds.

Now we can see what *the requirements for the requirements* might be and according to this we can see what it takes to the concept to *be suitable to fulfil them* – what was the definition of quality. It can be discussed, whether the goodness and quality should be linked at all.

As a conclusion, it is rather challenging to make requirements for "goodness" to an existing products and it is fairly impossible for a concept. There is lot of minor details not specified in the concept and thus the requirements for it can't fulfil the Hubka's five points (1 Complete, 2 Correct, 3 Quantified, 4 Qualified, and 5 Formalized).

Table 2. Suistoranta's presentation of seven universal virtues according to Andreasen and Olesen and their elements in three worlds according Popper

	COST	TIME	QUALITY	EFFICIENCY	FLEXIBILITY	RISK	ENVIRONMENT
WORLD 1	LAND	PHYSICAL QUANTITY: $t = s \div c$	SITE OF OPERATION, ENVIRONMENT	RESOURCES	CHANGES IN PHYSICAL CONDITIONS, EVOLUTION	PHYSICAL EVENTS	SPACE, TIME, ECOSYSTEM, ENVIRONMENTAL EFFECTS, WEATHER
WORLD 2	SACRIFICE, GREED, APPRECIATION, DESIRE	URGENCY TEDIUM	PERCEPTION, FEELING, VANITY, PRIDE	INDOLENCE, ASPIRATION TO CONVENIENCE	"RELATIVE EASINESS"	AMBIVALENCE, SENSE OF SELF-PROTECTION, FEAR	INSTINCT, REGIONALISM, TRAUMA OF UPROOTING
WORLD 3	CAPITAL, LABOR, PROPERTY	TIME VALUE, FUTURE VALUE, FASHION, TRENDS, SCHEDULES, RATE OF INTEREST	CODES, STANDARDS, SPECIFICATIONS, STATUS	FUNCTIONS, EFFECTS, RESULTS	CHANGES IN OPERATIONAL CONDITIONS, DEVELOPMENT	EFFECTS OF ACCIDENT, LOSSES, PENALTIES, RESPONSIBILITY	OUTPUT OF TECHNICAL SYSTEMS, NATURE CONSERVATION, HYGIENE

3. The approach of behaviour and life cycle condolence

In the table 1, we see that most of the Hubka's *External Properties* are more or less related to technical systems condolence to life cycle (and production process) phases. Thus we could instead of thinking the requirements, take the life cycle view and try to figure out how the properties designed in the concept will affect its suitability to later production and life-cycle phases. This kind of approach is proposed for example by Mikkel Mørup in his thesis "Design for Quality" [Mørup 1993].
In the "big and small Q" –approach idea is that there are external and internal qualities which are called "Q" and "q". According Mørup the Q-quality is the customer's qualitative perception of the product and q-quality is the internal stakeholder's qualitative perception of the product in relation to his product related tasks. The important part of this Q/q-thinking is linking of the quality issues to the lifecycle phases of the project. After this we are very near to see, where the quality decisions are made and what kind of consequences (sometimes called *dispositional mechanism* [Andreasen and Olesen 1990]) they have in later life cycle phases. According to this Mørup defines that both Q and q are vectors. In q-quality vector one can see position of many quality tools. However their most important meaning is to form a mind-set of the achieving quality. The q-quality properties are under direct control of the designer and at least from theoretical viewpoint the positive of these is the objective of robust design. Understanding the dispositional mechanisms can form a base for design rules, principles of robust design and not least the designers' internal quality oriented mindset. So the promising approach for early phase concept evaluation could be the understanding and management of the dispositions.

3.1 Research hypothesis

Theory of Technical Systems [Hubka and Eder 1984] defines the internal and external properties of technical systems. The internal properties are properties which the designer has direct control. The external properties are the properties the technical system carries (see table 1) by the definition. The disposition theory by Olesen (1992) gives another way of thinking of these properties. Instead of connecting all the properties to the product some of the Hubka's defined properties can be thought as properties of the business environment. At the concept design phase the knowledge about the concept is very limited and the determination of the external properties is impossible. We define properties of the business environment which are independent and not defined by the concept. Hence we can define and examine the properties of the business environment even there are many open questions in the concept. From this deduction we get our hypothesis for this research:

Every concept has certain set of properties and every business environment has certain set of properties and these properties define the behaviour of that concept in the current business environment.

In theory concept and business environment could have infinite number of properties. There exists multiple ontology defining variable sets of properties so there is always situation that another property could be added to the concept or to the business environment. In practise this is not the case as the concept space is definite and the behaviour is defined in that space.

Our hypothesis is not directly conflicting the referred theories, but it cannot be proved either by these theories. Therefore the hypothesis has to be proved in other way, what is done in this research by creating a tool based on the above mentioned principles. In the creation and testing of the tool one can see indications about the tenability of our hypothesis. To prove that a statement is always true is very difficult so we approach the proving by falsification. We examine three claims against our hypothesis. If any of these claims proves to be true, it means that our hypothesis is incorrect. These claims (the negative indications) are:

1. It is not possible to construct relevant and acceptable comprehensive lists of the properties of the concept and properties of the business environment.
2. It is not possible to find relevant comparing elements between the properties of the concept and the business environment.
3. The results lack practical value.

The first indication means in practice that it would not be possible to formulise lists of properties which can be used to represent the concept or the business environment. The second indication states that the two types of properties represent such a different scientific approaches that they are not compatible. The third indication is a strong argument, that the hypothesis might be feasible, but tools developed out of it do not have any explaining power over normal common sense. In this case the approach is futile as it does not add your knowledge.

If a prototype tool without definitive failures mentioned above can be made, it is proven that there exists at least one case, where the hypothesis is supposed to be valid. This opens a possibility to have a concept evaluating tool, which shows out the problematic points in the concept, when it comes under stress of the life-cycle. This has a clear analogy to Finite Element Model FEM –calculation and similarly this approach could be called *concept-FEM.*

4. Concept evaluation

The concept evaluation tool is presented in the figure 2. The tool resembles the Quality Function Deployment [Taguchi 1986] matrix tool by appearance, but our tool presents what are the behaviours of the concept in the business environment.

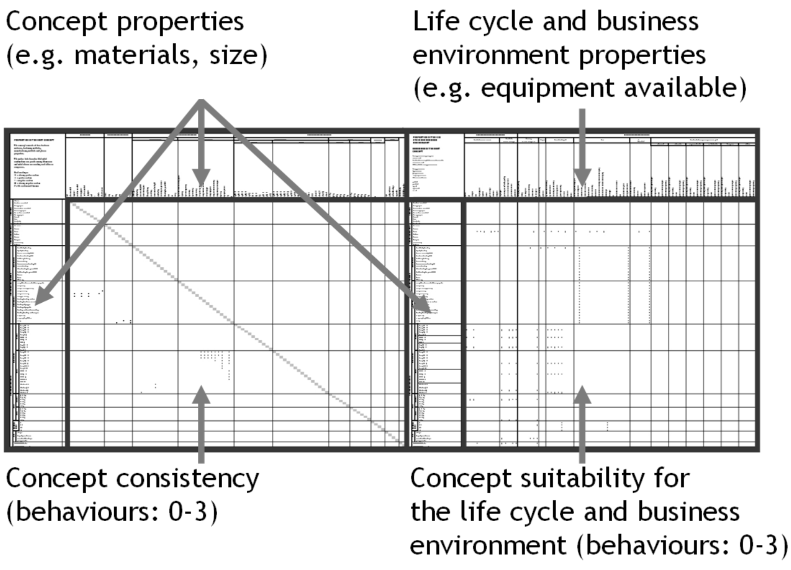

Figure 2. The layout of the concept evaluation tool

The concept evaluation tool can be used fast for the estimation of a consistency of the product concept and its suitability for the life cycle and production network. Evaluation process (see figure 3) has been divided into four phases that are listed below:

1. Clarification of the properties of the concept
2. Clarification of the properties of the life cycle and business environment
3. Evaluation of the consistency of the concept
4. Evaluation of the suitability of the concept for the life cycle and business environment

The first two phases are preparation for the actual evaluation that happens in the third and the fourth phase. By comparing two concept properties together the behaviour between them can be discovered. In other words two properties cause certain behaviour. The idea is that properties are listed beforehand the evaluation process.

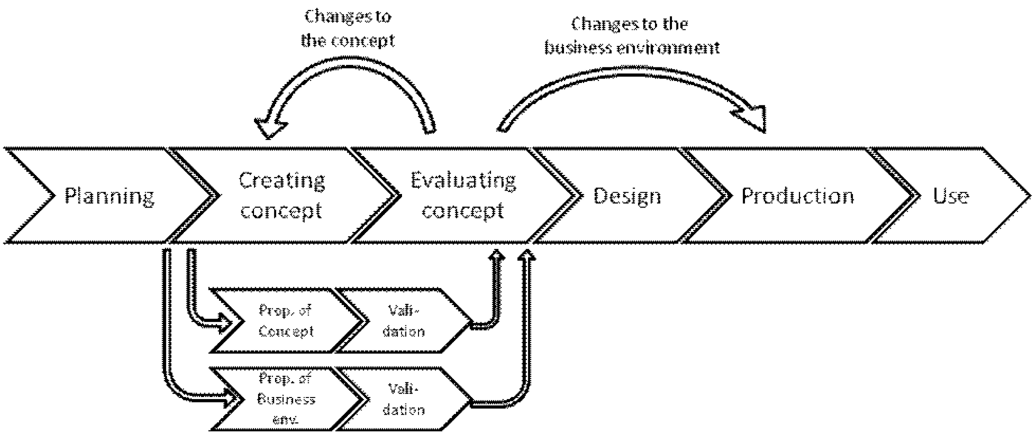

Figure 3. The phases and the effects of the concept evaluation tool to the product development. The life cycle model is simplified for the picture e.g. missing phases after the use.

The product concept and its life cycle are outlined in the planning phase. This contains the rough limitation of the possible manufacturing methods, and also the decisions about the business environment in which the final product will be fit in. Use of our tool is located at the very beginning of the concept phase where the new concepts are formulated. This is the point where designers need a way to quickly validate their new concepts relative to the production network and business environment. It might be the case that the new concept would be easily manufactured but not in the current production network or it does not fit in to the desired value chain. Our tool aims to point out such inconsistency as early as possible to avoid wasting time in development of unsuitable concepts.

4.1 The properties of the concept

The first phase of the concept evaluation is to identify the properties that the concept comprises. In the boat industry the properties can be divided in four main groups that consist of materials, manufacturing methods, fastening methods and physical properties. The boats and their parts can be manufactured from several different materials, such as from aluminium, glass fibre, steel and wood. Even if the parts have been manufactured of the same materials, they can be made using many different technologies. Also there are several methods for fastening the parts together like for example glueing, welding, and screw fixation. The physical properties are related to measurements, weights, number of parts, form and robustness.

If there does exist other important properties, which are not presented at the tool, they can be manually added. In that case it has to be worked out also to what already listed properties the new added property has an effect and what kind of effect and behaviour they have on each other. The means of describing the behaviour between the properties are explained in more detail in description of phase three in Chapter 4.3.

4.2 The properties of the life cycle and business environment

The properties of the life cycle and business environment are listed in two main groups in the second phase: properties that are linked with value chains and with processes and services. On the background of this division is Company Strategic Landscape (CSL) framework model [Juuti et al. 2007]. CSL-framework model describes underlying important factors that need to be taken into account when the best possible product structure-process pair is to be discovered.

In boat industry as well as in other fields the product needs to be suitable for the chosen value chain. Value chains include phases that improve the value of the product. For example the working phase where edges of a window are sealed the added value to customer is the waterproofness. The properties which are linked to the value chains in the boat industry are divided in properties of the suitability for the environment of use, and properties of the suitability for the environment of logistics. Above-mentioned value chains guide possible product structures, which represents from what parts the product concept consists of and how the parts are placed on the product. The situation can also be thought vice versa, in other words the chosen product structure makes the operating only in certain value chains possible. The properties of value chains are determined based on the strategy and goals of business and again situation is bidirectional, certain value chains make it possible to implement only certain strategies.

Behind the processes and services are resources and structure of the network of the company and the chosen ways of action. The processes and services contain properties from the point of view of planning and information management, capacity, know-how and capability, economy and ability to take risks and order-delivery processes. CSL-framework model explains that the chosen strategy and goals of business guides the activities of the organisation, but the structure of the existing organisation affects the possible strategies on the other hand.

The focal point in the model is to understand the connection between the product structure and the delivery process. At the development of a new product the objective is to find among themselves the best compatible product structure / delivery process pairs that support the chosen objectives. If a delivery process does not for example contain possibility to the welding, certain product structures will not be possible.

4.3 The consistency of the concept

The purpose of the first evaluation phase is to ensure that the concept is internally nonconflicting and theoretically realisation fit. The phase is carried out by comparing the properties of the concept which have been confirmed at the first phase. In the mutual comparison of two properties the behaviour between them is found out. These behaviours can be described in many different ways but in this approach division for five different classes is used which can be seen from table 3.

Table 3. Notation used for description of behaviours between the properties

Evaluation scale	Description of behaviour
3	Strong positive
2	Positive
1	Negative
0	Strong negative
?	Behaviour unknown

For example a control desk concept of the boat has been thought containing glass fibre parts which are manufactured with a vacuum injection. As a fastening method a screw fixation has been envisaged to the parts of the concept. Overall dimensions of the largest parts are 1000 x 500 x 5 mm (length x width x thickness) and the parts contain sharp corners. In that case for example the behaviour of material and the manufacturing method will be strongly positive (worth three points) because the vacuum injection is suitable for manufacturing of glass fibre parts. Whereas manufacturing method is evaluated in relation to the form, behaviour is negative (one point) in this case because it is difficult but not impossible to manufacture parts that contain sharp corners with the preceding method.

It is not necessary to compare all the properties. For example the comparison of material and the number of parts is not interesting because they are not interrelating with each other directly. However the manufacturing method affects the size of the parts so this behaviour must be estimated.
In the tool the properties of the concept and the behaviours between them have been presented with the help of the matrix in which the properties of the concept have been listed. The behaviours of the properties of the concept are presented in the matrix using numerical evaluation scale that is presented in table 3. These behaviours of the properties of the concept have been prefilled to the tool because they are based on general knowledge and are independent of the company that uses the tool.
When the consistency of a concept is under evaluation the properties that represent the concept are being chosen first. After that the tool gives an estimate as a result. This estimate that is based on the points can be utilized in decision-making about whether changes should be made in the concept or can it be continued to the next evaluation phase.

4.4 Suitability of the concept to a life cycle and business environment

When a positive decision on the previous phase has been obtained, the properties of the concept are estimated in relation to the properties of the life cycle and business environment. In this phase it is seen how well the concept suits for the network of the company and for the value chains. In the evaluation of the suitability for the network attention is paid to the subcontracting activity also in addition to own operation. The fourth phase differs from the third phase because the behaviours between the concept and the life cycle and business environment are not constants but company specific. This means that the evaluator has to evaluate the behaviours manually.
At the fourth phase, the properties which describe the concept will be chosen first (the same properties as at stage three). After this the evaluator uses number values from zero to three for marking of the behaviour that the property of the concept has in relation to the properties of the life cycle and business environment. The purpose of the numbers is the same as at phase three and as at phase three it is unnecessary to evaluate the every property pair but the pairs that are meaningful. The areas which are unnecessary to be examined are marked to the tool at a grey colour.
When the points have been filled the tool gives the summary about the scores received by the categories of properties. As a result it is seen for example if the preconditions for the manufacturing of the concept are sufficient in the present production network and what matters are acceptable and what requires development. One question to be thought is whether to do the changes in the concept or the network of the company in problem situations. Referring to this, the tool can be used also in situations in which the concept has been already selected but the problem is the finding of the suitable subcontractors. In this case on the basis of the properties of the concept each subcontractor can be evaluated separately according to the properties of the life cycle and business environment.

5. Conclusions

The tool developed in this research and its testing's and evaluation made in the industry case proves our hypothesis valid. The first negative indication can be shown false based on the fact that in our tool the set of properties is always concept-specific. Only those alternatives which are feasible in reality are collected to the set in question. In our example case the defined properties were based on the common understanding about the technical features and verified and fulfilled by the experts of the company. Thus the list of the properties of the concepts surely contains those properties which are relevant by the concept in question. The properties of the business environment were determined as a set which will cover the phases of the whole lifespan. Our case product is from a specific industrial field, but our goal in the research was to create a user-friendly tool, thus the tool is not application sensitive. But then we did not aim to create a universal set of properties. In case of aiming for universal definition example STEP standard could be used for the representation of the concept. In our case the STEP standard defines example the 3D model in too abstract way and for that reason cannot be used to represent the properties in the concept evaluation tool.
The second indication was disproven by the behaviour found between the properties of the concept and the business environment. We were able to classify different types of behaviour and the magnitude of their effect. Some of the behaviours are either-or type, meaning there wasn't any intermediate form

between them. This was the case mainly on the mutual properties of the concept. Every property of the concept does not interact with all the properties of the business environment. Such properties where concealed from the tool to prevent faults in the deduction of the behaviour. The existing behaviour between these two types are relational and the relations are presented in evaluation scales and further on used to calculate the final value for the suitability of the concept to the business environment.
On the contrary to the third negative indication the practical value of the tool is significant for the designers. Designing of extensive and/or complex product requires multidisciplinary knowledge. This knowledge is in many cases tacit knowledge inside the design teams and is not exploited well. Our tool visualises the tacit knowledge converting it to explicit knowledge and furthermore increases the engineering know-how (see figure 4). The modelling of complex product has some challenges as one model covering a product build up from various types of materials turns the interpretation of the tool more demanding. Resolution for handling complex product is grouping of the properties, which enables to specify what sections of the concept are feasible for the business environment and which are not.

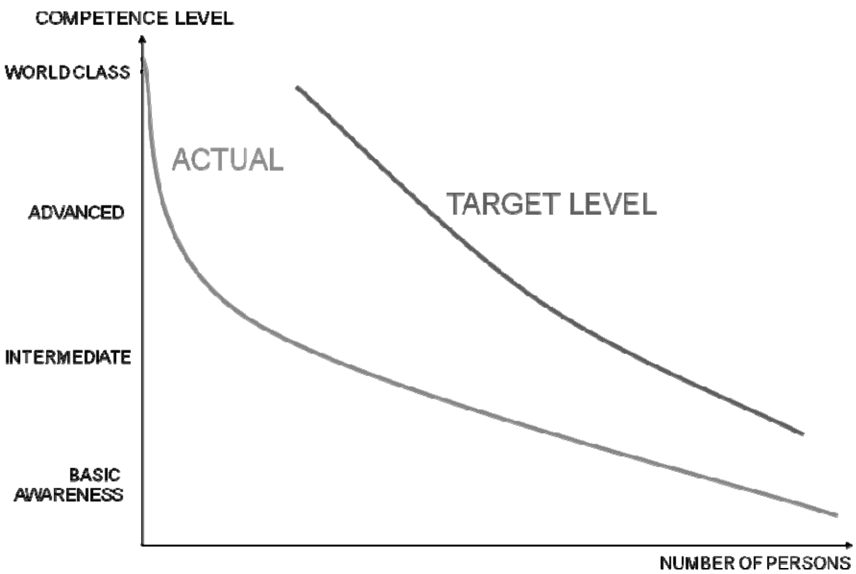

Figure 4. The tool's increasing effect to the designers' competence level. In the target level more designers have more know-how about the concept and business environment

The properties of the boat case were defined fully covering the possible concept variants in the boat industry. Only the properties which could be validated relevant for the concept were fed into the tool. This fact does not exclude the possibility to find similarly feasible properties for any other industry area products. The clusters of the business environment properties do not change significantly following the concept but they are dependent on the business drivers of the company.

6. Discussion

To summarise we can say that the first step of the tool creation was successful. The designers incorporating in the tool development and testing were able to see how the concept fit in to their company production network and to the business environment. In addition to this the tool also illustrates what are the frailties and are they in the concept properties or in the business environment properties. From this information the designer knows is it better to change the concept or the business environment. This was a facilitating factor at this stage and the following task is the testing of the tool in a totally different environment. Our future works focuses on more detailed description of the tool in practice.

Acknowledgements

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