Creative Design process

CDP

by

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Contents

Chapter 1

Introduction

This lecture notes presents design methods and approaches that can be useful to students as a designer, both during your time as a student and as a professional. Design methods are not recipes for success, just like strictly following a cooking recipe is not a guarantee of a good meal. Methods will help you to structure your thinking and actions. In this lecture notes, we present the essential steps that will enable you to work efficiently and achieve your goals without too many deviations. Furthermore, the methods will help you to communicate with your team or client. Hence, you will not lose your way in complex design processes. Designing distinguish itself from other disciplines in that it combines a number of activities, such as visualising, creative thinking, empathising with the intended users and reasoning from values via functions to forms. Designing requires you to cope with uncertainty and to play with possibilities, leading to new insights that can result in innovations. Questions that you may ask yourself are;

- What questions do I need to answer? How and when?
- What activities do I need to execute? When and in which order?
- How do I determine the boundaries of the context i am designing for?
- How can map the 'world' of my intended users?
- When can I stop analysing and start creating and how do I generate ideas?
- How do I choose between the generated solutions?

Design methods and tools can help you answer these and many other questions. In this lecture notes the approach is the stage approach which attempts to understand creativity by breaking it down in to stages.

Chapter 2

Design Stages

Based on earlier work of the creative process, Wallas (1926) formalised the four-stage model of creativity. Wallas defined creativity as a linear four-stage model, progressing through the stages of observation, brainstorming, prototyping and implementation. Figure 2.1 shows the design stages. During each stage a number of features needs to be taken. To inspire your creativity we have added to each stage the divergence and convergence aspects:

1. **Divergence:** Stimulating new thinking by diversifying and exploring.

2. **Convergence:** Refining and choosing the best possibilities.

Each of the phase include a set of steps, which rely on techniques that produces specific document files that provide understanding about the project. Moreover, each phase consists of steps that lead to specific deliverables. The system evolves through gradual refinement in each phase.

2.1 Design cycle

The model describes the different stages a designer goes through when solving a design problem. Theoretically designer can go through just a single cycle, however usually it will undertake many iterations. Ideally, designer spirals from problem to solution, from abstract to concrete, from function to product geometry. Usually this is an iterative process where designer has to take a few steps back in order to go a step further. Being aware of the basic cycle that you are going through, helps you as a designer to organise your thoughts and design activities. Figure 2.2 shows the design cycle as an iterative process [1].

The design process does not involve just one creative phase or one analytical phase; these activities are ongoing continuously. This means that there is not one creative phase after which you stop being creative. You must engage in creative thinking throughout the process. If you get lost in your ideas and thoughts, perhaps is it helpful to consider which stage of the design cycle you are in and to discuss it with team members or experts. Note the central role of the designer in this context. The marketing aspects of the product design as indicated in Figures 2.1 and 2.2 will not be treated and discussed in this course. It will be examined in other course ?????.

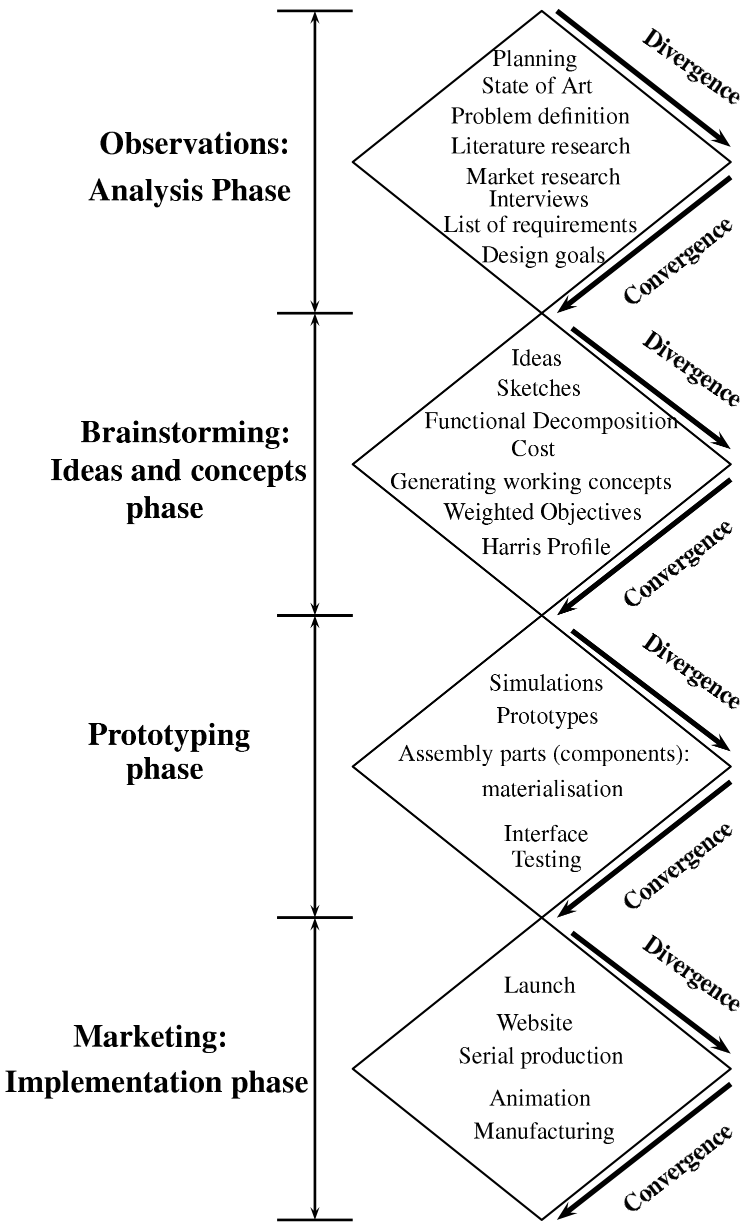

Figure 2.1: Design stages.

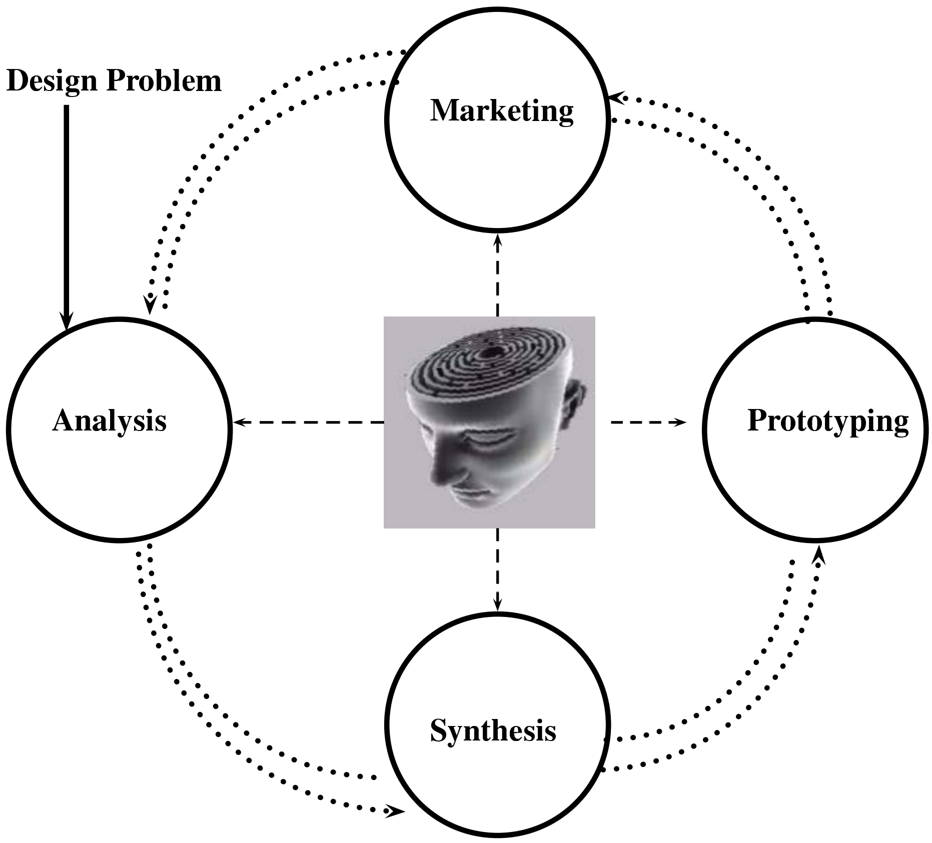

Figure 2.2: Designing is an iterative process.

Chapter 3

Analysis Phase

In this chapter a general overview of tasks to be executed during the analysis phase are addressed. These features are as follows: literature research, problem definition, defining the list of requirements and the design goals, planning, etc.

3.1 Literature Research

In writing the literature research, your purpose is to convey to your reader what knowledge and ideas have been established on a topic, and what their strengths and weaknesses are. As a piece of writing, the literature review must be defined by a guiding concept e.g., your research objective, the problem or issue you are discussing [2]. Ask yourself questions like these:

1. What is the specific thesis, problem, or research question that my literature review helps to define?

2. What type of literature review am I conducting? Am I looking at issues of theory? methodology? policy? quantitative research (e.g. on the effectiveness of a new procedure)? qualitative research (e.g., studies of loneliness among migrant workers)?

3. What is the scope of my literature review? What types of publications am I using (e.g., journals, books, government documents, popular media)? What discipline am I working in (e.g., engineering, nursing psychology, sociology, medicine)?

4. How good was my information seeking? Has my search been wide enough to ensure Ive found all the relevant material? Has it been narrow enough to exclude irrelevant material? Is the number of sources Ive used appropriate for the length of my project and report?

5. Have I critically analysed the literature I use? Do I follow through a set of concepts and questions, comparing items to each other in the ways they deal

with them? Instead of just listing and summarizing items, do I assess them, discussing strengths and weaknesses?

6. Will the reader find my literature review relevant, appropriate, and useful?

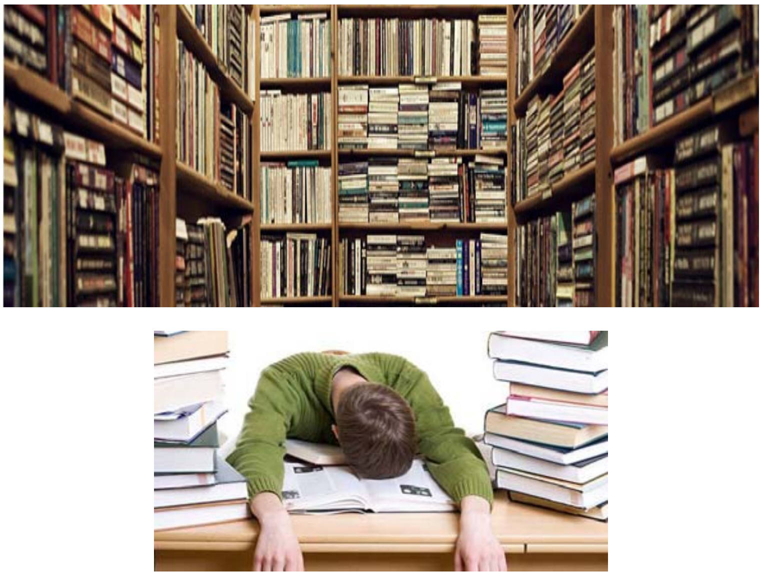

Figure 3.1: Optimal literature research would provide answers to questions related to the project.

After the literature research, you should have a thorough understanding and answers to the following features:

- Goals of the project.
- State of art.
- Problem definition.
- List of requirements.
- Project deadline.
- Is there anything that would prevent the project from being successful?

3.2 Problem definition

Designing is often referred to as problem solving. Before you start solving anything, you need to be certain that you are working on the appropriate problem. Finding and defining the real problem is a significant step towards a solution. Answering the following questions with help you to create a problem definition:

- What is the problem?

Figure 3.2: Finding the problem is a significant step toward the solution.

- Who has the problem?
- What are relevant context factors?
- What are the goals?
- What are the side effects to be avoided?
- Which actions are admissible?

The outcome is a structured description of the design problem, with a clear description of the desired end situation (goals) and possibly the direction of idea generation. A well-written Problem Definition provides a shared understanding between you, your client and possible stakeholders. Limitation is that defining the problem does not offer you the solution.

3.3 List of Requirements

A List of Requirements (LoR) states the important characteristics that your design must meet in order to be successful. A LoR describes concretely all of your design objectives and can be used to select the most promising ideas, concepts, and design proposal(s) or combination of proposals. The first step is to define as many requirements as possible. Make a distinction between demands and wishes: demands must be met. Next eliminate requirements that are similar or do not discriminate between design alternatives. It is beneficial to identify whether there is a hierarchy of requirements. Requirements fulfil the following conditions:

- Each requirements must be valid.
- List must be complete.
- requirements should be operational.
- List must be non-redundant.
- List must be concise.
- Requirements must be practicable.

Figure 3.3: What started out as a grduation project at the Faculty of Industrial Design Engineering in TU Delft resulted in a successful product and successful launch of the company Senz°. The main design requirement was that it should be able to withstand wind speed of 100km/h. And it does.

Spending too much time on analysing and defining design requirements can hinder your creative process. Employing an iterative approach switching between sketching, eg. creating and defining criteria. Moreover do not limit the possibilities of your design by defining too many requirements.

3.4 Planning

After getting the answers you need, think about the tasks that are outlined in the scope of work and try to come up with a project planning and management approach by sketching something very high-level on paper. All you need is a calendar to check dates. A first sketch can be very rough, make sure your sketch includes [3]:

- Deliverables and the tasks taken to create them.
- Your clients approval process.
- Time frames associated with tasks/deliverables.
- Ideas on resources needed for tasks/deliverables.
- A list of the assumptions youre making in the plan.
- A list of absolutes as they relate to the project budget and/or deadlines.

Try to make a simple project plan, the more straightforward and easier to read it is - the better. No matter what tool youre using, you should include these features:

- Include all pertinent project info:
  - Client Name, Project Name.
  - Version Number, Delivery Date.
- Break out milestones and deliverables in sections by creating headers and indenting subsequent tasks.

- Call out which team member is responsible for each task so there is no confusion about who is responsible for what.
- Be sure to show durations of tasks clearly. Each task should have a start and an end date.
- Add notes to tasks that might seem confusing, or need explanation.
- Call out project dependencies. These are important when youre planning for the risk of delays.

Chapter 4

Ideas and Concept Phase

For many companies and hence for your project, making use of ideation is frequently a good attempt to initiate the first endeavour for developing the solution to a given problem. There are numerous ideation techniques addressed in the literature [4]. For ideation we will examine the brainstorm and Morphological analysis techniques. It is essential to think out of box during the ideation phase.

4.1 Brainstorm

Brainstorming can be useful during each phase of the design process, especially when starting up the generation of ideas after defining the design problem and the first set of design requirements [1].

Figure 4.1: Generating ideas using brainstorm is similar to swarming.

A brainstorm is usually carried out with a group of people. In practice, any number between 4 to 15 attendance will work. A number of guidelines should be followed during the session:

- Criticism is postponed: during the session you should try **not** to think about utility, importance, criteria, feasibility and the preferences. You should not make any critical remarks. Participants should feel free for their suggestions.
- Any idea is welcomed. An atmosphere must be created where Participants should feel free and secure.
- Combination and improvements of ideas are desired: you should endeavour to generate better ideas by building upon the previous ideas.

4.1.1 Possible procedure

Possible procedure can be as follows.
step 1:

- Using the defined problem addressed in the previous chapter, develop problem statement, for example a 'How-To'. Select a team of participants. Draw up a plan for the session including a timeline and the method to be used.
- Have a preparatory meeting with the team to explain the method and guidelines.
- At the beginning of the session write the problem statement and the four rules on a blackboard or flip chart.
- As facilitator asks a provocative question and write down the group's response on the flip chart.

step 2:

- Once many ideas have been generated, the group selects the most promising ideas or cluster of ideas. Usually some criteria are used in this selection process.
- The ideas or cluster of ideas are taken to the next phase, namely concept phase.

These steps can be carried out using discussion: brainstorm; writing: brain writing; drawing: brain drawing.

4.2 Morphological Chart

This technique helps you to generate ideas. A morphological chart is a visual way to capture the necessary product functionality and explore alternative means and combinations of achieving that functionality. For each element of product function, there may be a number of possible solutions. The chart enables these solutions to be expressed and provides a structure for considering alternative combinations. This can enable the early consideration of the product 'architecture' through the generation and consideration of different combinations of 'sub-solutions' that have not previously been identified. Used appropriately, it can help to encourage a user driven approach to the generation of potential solution. Figure 4.2 shows an example of a morphological chart for a pedal kart.

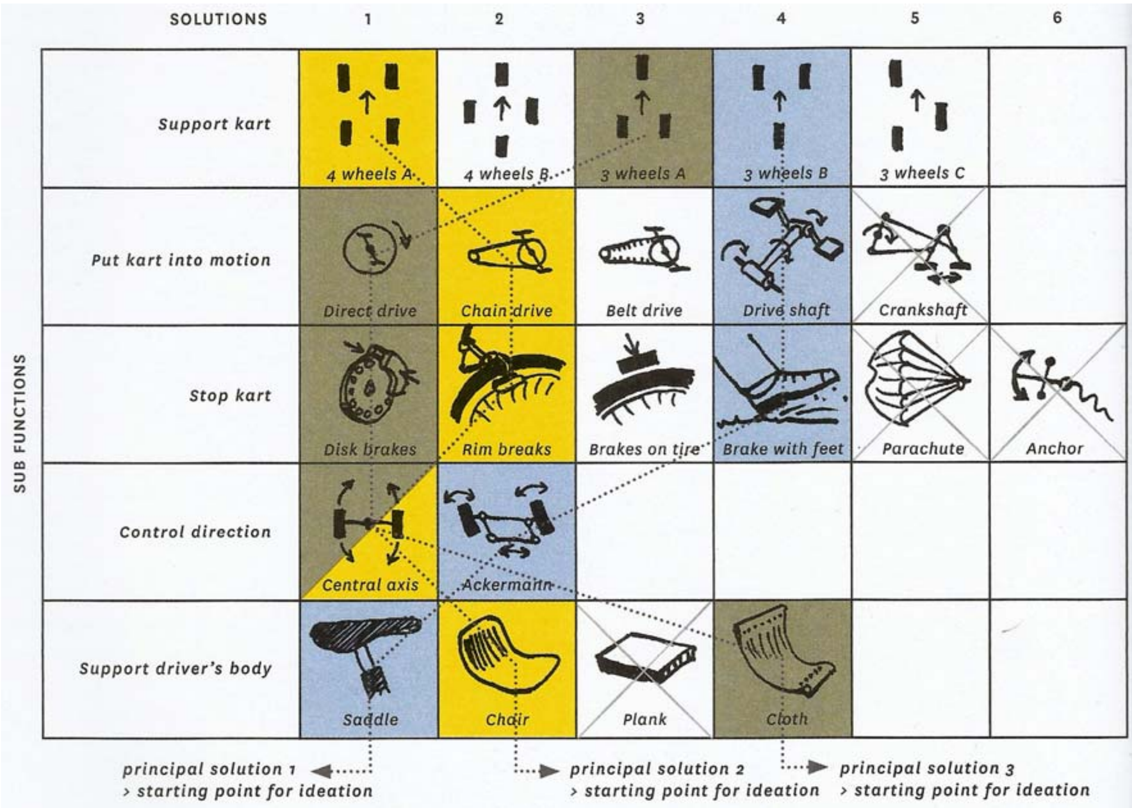

Figure 4.2: An example of a morphological chart for a pedal kart.

4.2.1 How to use the method?

The starting points of a morphological chart are a well-defined main function of the product and a function analysis of the product; the product should be decomposed in terms of its function and sub-functions. The sub-functions describe the characteristics that a product normally should contain in order to function properly. The description of a function always contains a verb and an object. In a morphological chart, functions and sub-functions are independent and have no reference to material features. Through careful selection and combination of a set sub-solutions, a "principal solution" is formed. Generating solutions is thus a process of systematically combining sub-solutions.

4.2.2 Possible procedure

Possible procedure can be as follows.
step 1:

- Formulate the main function of the product.

step 2:

- Identify all the needed functions and sub-functions.

step 3:

- Construct a matrix with the sub-functions as rows.

step 4:

- Fill the rows with all the possible solutions. Think out of box to be innovative. Solutions can be found using literatures, analysing similar devices, or new principles.

step 5:

- Create ”possible solutions” by combining one solution per row for each sub-solution.

step 6:

- Carefully analyse and evaluate all solutions with regard to the design requirements and choose at least three principal solutions.

- Sketch possible ideas for the complete device based on each principal.

4.2.3 Proper use of the method

The possible combinations for solutions increase tremendously quickly; a 10×10 matrix yields 10^{10} solutions. In order to limit the number of options, analyse the rows critically and group the solutions before making the combinations.
For the analysis of the rows you can rank the solutions per sub-function in order of first and second preference using the design requirements.
Group the sub-functions in groups of decreasing importance. As a first step, only evaluate the most important sub-function group. After you have chosen one or more combinations of solutions, only these are considered for evaluations.
Challenge yourself by making counterintuitive combinations of solutions.

4.3 Concept Selection

The need to select one concept from many raises several questions:

- How can the team choose the best concept, given that the designs are still quite abstract?
- How can a decision be made that is embraced by the whole team?
- How can desirable attributes of otherwise weak concepts be identified and used?
- How can the decision-making process be documented?

Concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation, testing, or development. The method presented is also useful later in the development process when the team must select subsystem concepts, components, and production processes. There are a number of methods to be used for choosing the most promising concepts: Harris Profile, C-Box, Itemized response and PMI, Datum Method, Value, and Weighted Objectives.

Figure 4.3: Concept Selection: a complex process.

The weighted objectives and Harris Profile will be discuss in this chapter.

4.3.1 Weighted Objectives

The next step of the design process is to choose the most promising concept. The weighted objectives method is best used when a decision has to be made between a selected number of design alternatives, design concepts or principal solutions. The chosen concept then will be developed in detail design and fro embodiment. The weighted objectives enables you to sum up the score of all the criteria into a numerical value for each design concept.

This method assigns scores to the degree to which a design alternative satisfies a criterion. However, the chosen criteria that are used to evaluate the design alternatives might differ in their importance. For example, the cost price might be of less importance then appealing aesthetic, see Apple products. This method allows you to take into account the difference in importance between criteria by assigning weights according to their importance for evaluation. The weight is usually ranked between 1-5 or 1-10. Possible procedure can be as follows.
step 1:

- Select the criteria according to which the selection will be made.

step 2:

- Choose three promising concepts from your idea generation.

step 3:

- Assign weight to the criteria.

step 4:

- Construct a matrix, with criteria in rows and the concepts in columns.

step 5:

- Attribute values to how each concept meets a criterion.

step 6:

- determine the overall score of each concept by summing up the scores on each criterion.

- Concept with the highest score is the preferred concept.

It is possible that this method gives error while you are assigning the weights. Hence it is recommended to resolve this problem through discussion with the project team.

4.3.2 Harris Profile

Whenever a number of alternative product concepts need to be compared and evaluated, the Harris Profile can be used to make your or your teaḿs evaluation explicit. As designers make some of their evaluations intuitively, the Harris Profile can help you to make those intuitions explicit so that you can discuss them with other stakeholders. A Harris Profile can be useful during each phase of the design process, but typically it is used after an idea generation phase when ideas or concepts need to be eliminated.

4.3.2.1 How to use the method?

Create a Harris Profile for each alternative design concept. A Harris Profile consists of an assessment of how the concept meets each of the listed design requirements. The evaluations are relative, comparing the different concepts in terms of their performance in each criterion. A four point scale is typically used to score the concepts. You should interpret the meaning of the scale positions: -2 = bad, -1 = moderate, et cetera. Thanks to the visual representation, decision makers can quickly view the overall score of each design alternative for all the criteria, and compare them easily. An important role of the Harris Profile is to make your evaluation explicit and easy to understand: it can help to stimulate discussion with your projects stakeholders in the early phases of design, when design requirements typically change as the concepts evolve and you gain a greater shared understanding of the design problem. Figure 4.4 shows the Harris profile for evaluating different alternatives to fix number of reports.

4.3.2.2 Possible procedure

Possible procedure can be as follows.
step 1:

- List the design requirements as fully as possible and rank them according to their importance for the design project.

step 2:

- Create a four-point scale matrix next to each requirement, coded -2, -1, +1, and +2.

step 3:

- Create a Harris Profile for each of the design alternatives by evaluating the relative performance of each alternative with respect to the requirements.

step 4:

- Create a Harris Profile for each of the design alternatives by evaluating the relative performance of each alternative with respect to the requirements.

step 5:

- Present the profiles next to each other to allow discussion with stakeholders and to determine which design concept has the best overall score.

4.3.2.3 Limitation of the Method

The four-point scales should be interpreted differently for each requirement and are not necessarily comparable. In addition the primary function of the profile is to communicate the evaluations that you have made after careful discussions and deliberations, and if necessary to open up discussion to sharpen the definitions of requirements or improve design concepts.

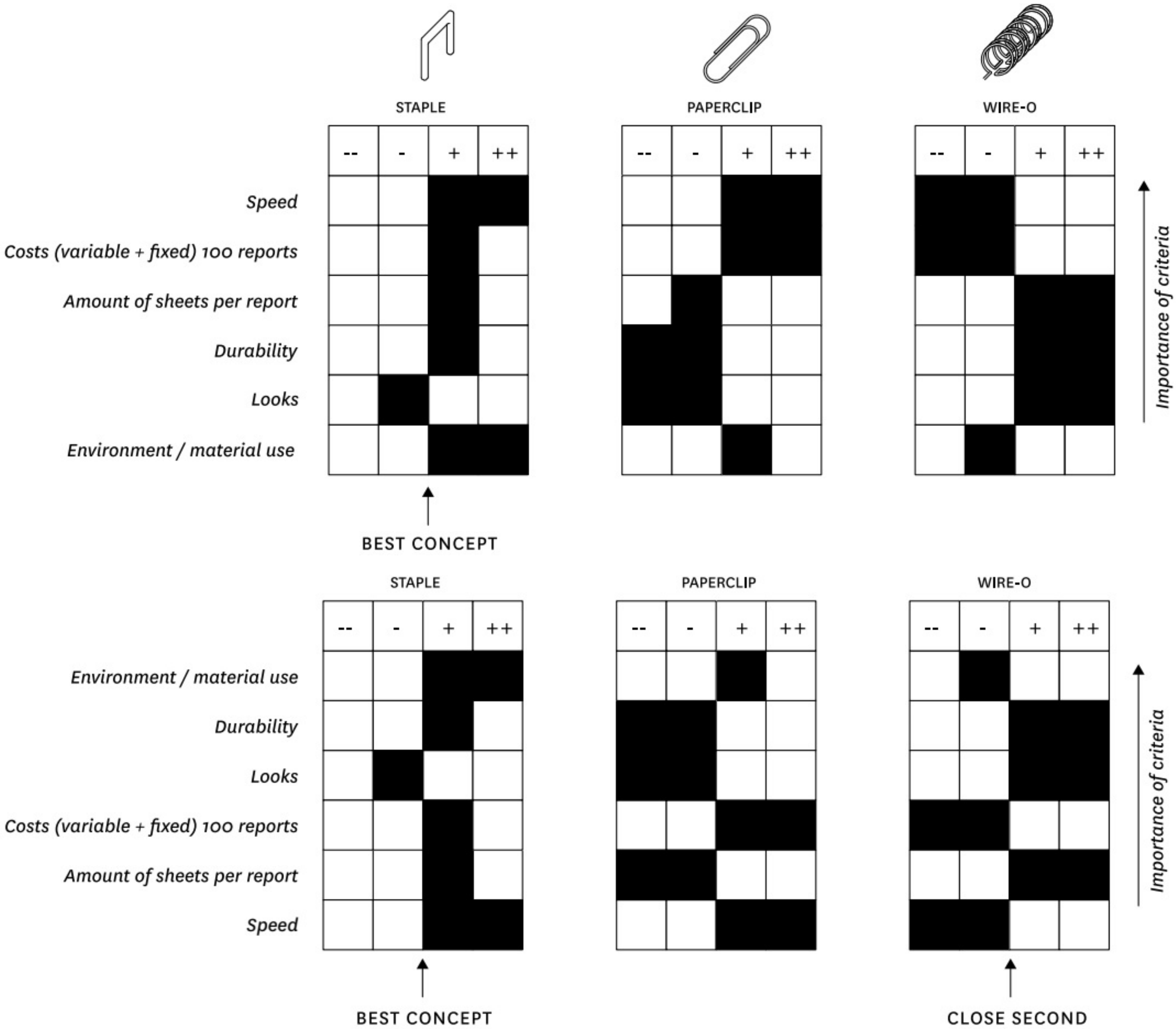

Figure 4.4: Harris Profile for project fixation of reports.

Chapter 5

Simulation and Prototyping Phase

The product and system behaviour can be simulated using 3-D multi-physics simulations which can be conducted to further fine-tune different components before creating prototypes for physical testing, reducing the overall product development time and cost while helping to ensure product reliability. It also allows system parameters to be improved to satisfy various performance targets.

5.1 Simulation

CAD (Computer-Aided Design) aims to built models that allow emulating the behaviour of components and facilities. The high competitiveness in industry, the little time available for product development and the high cost in terms of time and money of producing the initial prototypes means that the computer-aided design and analysis of products are taking on major importance. On the other hand, in most areas of engineering the components of a system are interconnected and belong to different domains of physics (mechanics, electrics, hydraulics, thermal...). When developing a complete multidisciplinary system or product, it needs to integrate a design procedure to ensure that it will be successfully achieved. Engineering systems require an analysis of their dynamic behaviour (evolution over time or path of their different variables). In order to perform rapid product optimisation iterations, the models must be formulated and evaluated in the most efficient way. Automated environments contribute to this.

There are many different CAD packages in the market. Some examples are SOLIDWORK for analysis the material slection, force and torque analysis, FEKO for ElectroMagentic (EM) radiation analysis, CST and HFFS for chip design. Figure **??** shows simulated model of different models in different packages.

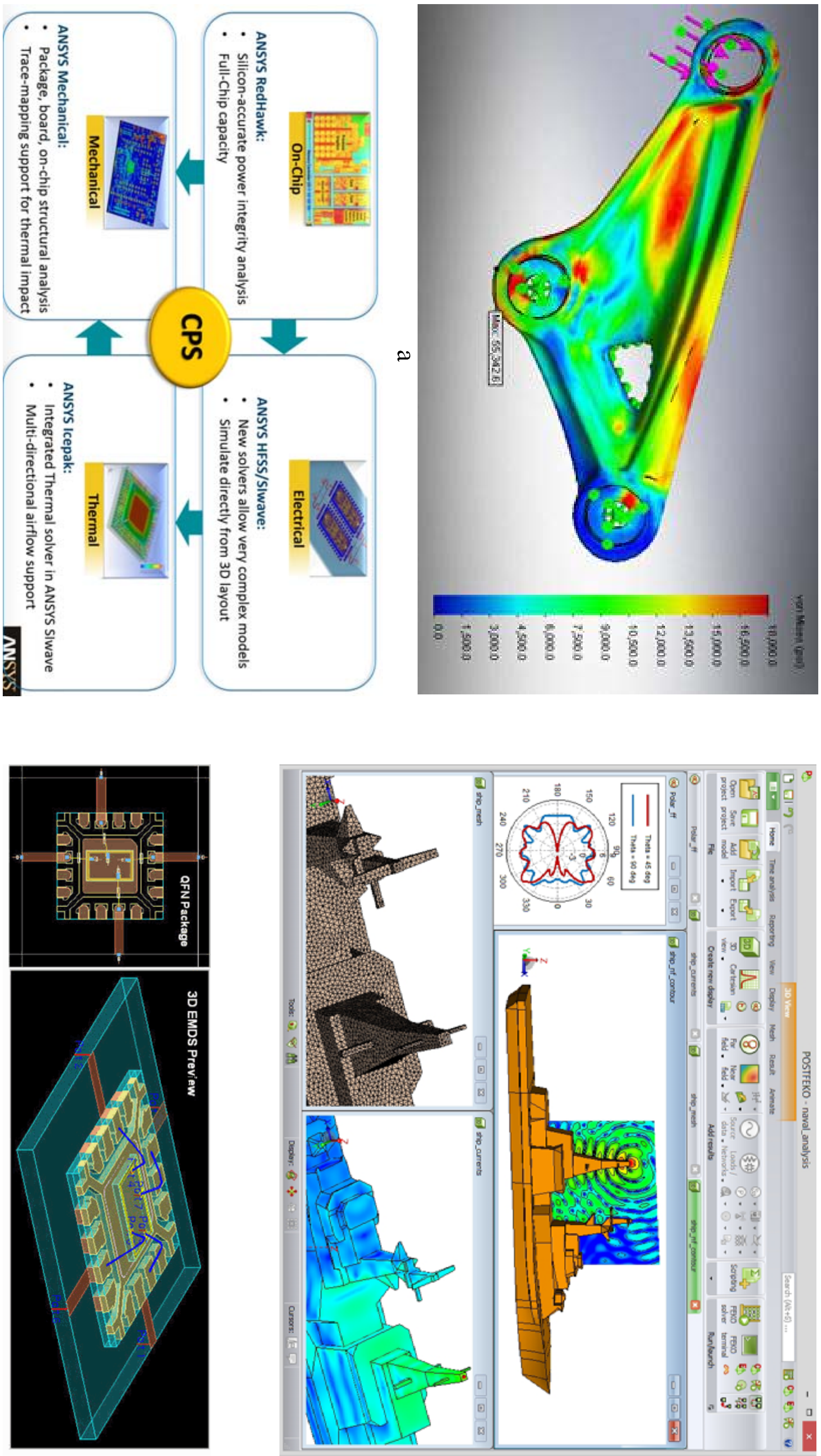

Figure 5.1: Simulated models: (a)Trek used SolidWorks simulation tools to reduce the number of physical prototypes required in designing its new racing bike; (b) Simulation of complete ship in FEKO for EM radiation analysis; (c) and (D) Chip design using CST and HFFS.

5.2 Prototyping

One of the best ways to gain insights in your chosen concept is to carry out some form of prototyping. This phase involves producing an early, inexpensive version of your design in order to discover any problems. Prototyping offers designers the opportunity to bring their ideas to life, test the practicability of the design, and to potentially investigate how a sample of users think and feel about a product. A possible guidelines for prototyping can be:

- Quick initiate of architect: if there are any uncertainties to your design then the best approach is to build it.
- Time: prototyping is about speed and testing.
- Build with main LoR and user in mind: test your prototype against the expected requirements and expected user response.

There are several methods of prototyping, namely role-playing, design drawing, technical documentation and 3-D models [1]. In this reader we only cover the 3-D models.

5.2.1 Three-dimensional models

Models are very often used in the practice of design and they play vital role in the product development process. The process of design happens not only in your minds, but also using your hands.In industry, models are used to test product functionalities aspects, change constructions and details, to interact with user in the desired context, and to reach consensus within company on the final form and productions process of the product. In mass production, working prototypes are used to test functionality and ergonomics. Changes that need to be made after the production preparation phase are often expensive and time consuming. The final prototypes thus facilitate the preparation and planning of production.

5.2.2 Why prototype[6]?

1. **Fail early and inexpensively** Real innovation always includes a risk of failure. Thomas Edison once joked, We now know a thousand ways not to build a light bulb. By building a prototype, you can quickly weed out the approaches that dont work to focus on the ones that do.

2. **Gather more accurate requirements** Almost half of all project costs are attributed to rework due to inadequate requirements. Traditional requirements gathering techniques such as interviews and focus groups can fall short because many people find it difficult to conceptualise a product before they see it. By developing a working prototype, you can demonstrate the functionality to help solidify requirements for the final design.

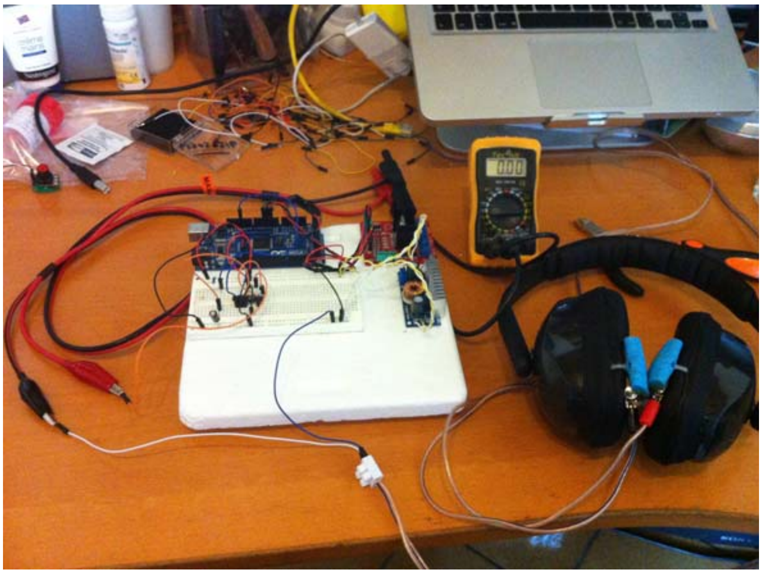

Figure 5.2: Quickly prototype your concept to discover the uncertainties to your design.

3. **testing and verifying ideas, concepts and LoR**: Proof-of-concept prototypes are used to verify whether certain technical principles actually work. They are simplifications: often details are left out and working principles are built.

4. **Technically understand the problem** It is unfortunate that system architecture must come so early in the design process because time only enhances your understanding of the problems that you may encounter. Have you ever thought, If I could go back in time, I would change ? By developing a functional prototype, you are forced to address both the foreseen and the unforeseen technical challenges of a devices design. Then, you can apply those solutions to a more elegant system design when you move to the final deployed solution.

5. **Resolve conflicts** The best engineers have strong opinions about how a given feature should be implemented. Inevitably, differences of opinion result in conflicts, and these conflicts can be difficult to resolve because both sides have only opinions, experience, and conjecture to refer to as evidence. By taking advantage of a prototyping platform, you can quickly conduct several different implementations of the feature and benchmark the resulting performance to analyse the trade-offs of each approach. This can save time, but it also ensures that you make the correct design decisions.

6. **Rally financial support** In the years since the dot-com bubble burst, investors such as venture capitalists have grown more risk-adverse when investing in start-ups. Even within larger companies, internal projects face

similar scrutiny from executives looking to maximize revenue. By developing a prototype to demonstrate the feasibility of your idea, you lower the risk of investment and therefore increase the probability that your idea will be funded.

7. **File patents more easily** Before 1880, all inventors had to present working models or prototypes of their inventions to the patent office as part of the patent application process. Today, the United States Patent and Trademark Office uses the first to invent rule, which grants a patent to the first inventor who conceives and reduces the technology or invention to practice. Though no longer required, a prototype is still the best and safest way to demonstrate reduction to practice. Furthermore, key components of a patent application, such as patent drawings and the inventors logbook.

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