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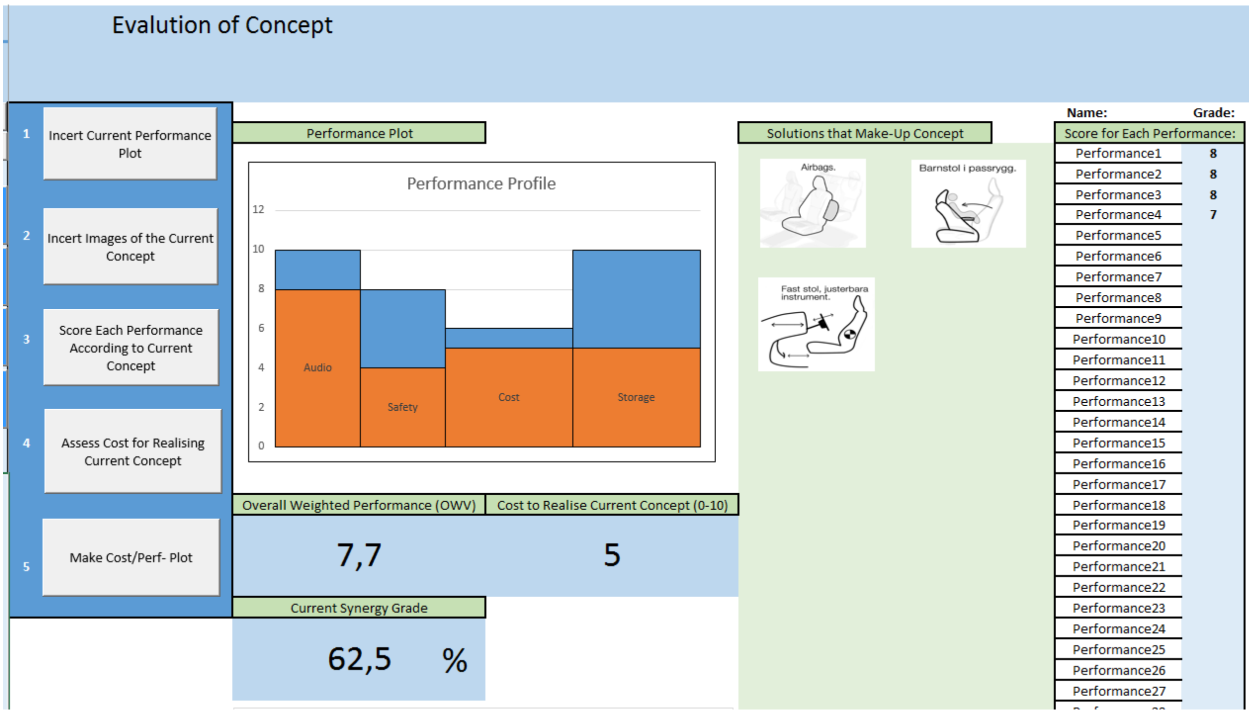

Simplify and Digitalize the "Balancing While Synthesizing"-Process

A method development project

Master's thesis in Product Development

Dennis Noubarpour

Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Master's thesis 2017

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Abstract

There exist many different product and concept development methods, many of these are very time and resource consuming. Furthermore, there are very few methods which include balancing activities between product properties. This is important since a desirable balance results in opportunities where further value may be achieved. Moreover, there is a risk of conflicts between product properties when the interaction is not taken into consideration, which can lead to costly loops. A concept development method, "Balancing While Synthesizing" was developed with the intent to be less resource consuming and incorporate the mentioned balancing activities.

Results from research projects showed that one step in the process was not intuitive enough and further development was needed. A method development project was conducted with the objective to make this particular step more intuitive. The project also includes a digitalization of the process, as a second objective, with the goal to achieve further improvements. A user needs list was generated through studying interview answers of past research and a theory study including interaction design principles. Different concepts for solving the objective were created and the needs were used as a screening tool by adding a weight to each need. The digitalization was made possible by finding the most suitable software package and planning the design through flowcharts and visual design. This made the implementation easier and less time consuming.

The final solution for the less intuitive step is made easier to use by introducing fewer alternatives to choose from while doing the balancing act, which makes the decision easier. The new solution also satisfied a hidden need for the process: saving values within iterations. This enables easier iterations in the future while no result is wasted in the process. The digitalization helps with the overall process, especially saving time and also keeping the process clean without any loss in quality of the tool.

Keywords: Decision making, Design methods, Evaluation, Method Development, Digitalization

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Dennis Noubarpour, Gothenburg, January 2017

Contents

Terminology

Read this section in chronological order. The basic terminology is on top and the rest builds upon it.

Function - A product property. What an element (system, part, component, organ, etc.) of a product, or human, actively or passively does in order to contribute to a certain purpose.

System - A structure which is separated from the surroundings by a borderline.

Sub-Solution - A system which is a subset of another system. A solution for a function.

Concept - A concept is a set of functions (see "Function" above) that makes up a possible solution for a product.

Balancing - Refers to the management of properties of a product concept in order to provide user value in a cost-efficient way.

Synthesis - The act of combining two entities in this case sub-solutions to form something new.

Synergy - A desirable balance between different product properties.

Performance - The measure of function and behavior – how well the device does what it is designed to do.

Digitalize - Digital transformation of in this project a non-digital process.

Design Parameters- These are engineering parameters such as material and manufacturing.

Functionality - Combination of all effects, actions, functions and their behavior, that contribute to making the product useful for an intended purpose.

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1
Introduction

This master thesis project is carried out within the Department of Product and Production Development at Chalmers University of Technology. The project aims to solve two objectives regarding method development. This section describes a background to the "Balancing While Synthesizing"-process as well as what the objectives are.

1.1 Background

Developing new ideas and iterating on existing ideas is one of the key activities that made humans throughout history enhance their living standards and improve the world around them. This gives product development its importance since it supports these activities. To develop ideas, especially when the ideas are not imagined by anyone before, can be difficult and overwhelming. Therefore, different methods have been developed to make it easier for individuals and teams to implement their ideas in a feasible fashion. Today, there are a lot of different product development methods and tools used in the industrial and academic world. One of these methods is the "Balancing While Synthesizing"-process [1], in this thesis the abbreviation “BWS-process” is used. The BWS-process is the core method this master thesis is based upon, hence section 1 focuses on clarifying what this process is and the benefits and the objectives of this master thesis.

1.1.1 Background of the "Balancing While Synthesizing"-Process

The "Balancing While Synthesizing"-process was first made public in 2005 [1] in the conference proceedings of the International Conference of Engineering Design 2005 (ICED’05). The method acts within the "Concept Development"- phase, in regards to the Ulrich and Eppinger generic product development process [33] illustrated in figure 1.1. A more thorough description of the process steps can be reviewed in section 3. In this stage it is important to generate different concepts, this is something that the BWS-process incorporated but not as a definite goal. According to Almefelt (2005) the goal with the process is:

- Enable concept development with vague information
- Enable cross-functional work in teams
- Focus attention on synergies between sub-solutions

- Evaluate overall performance in a performance/cost-ratio

Almefelt(2005) describes the goal with the method in this quote: "Since the method aims to be applied in the early concept phase, it must involve the use of vague information and engineering assessment. A further notion is that the approach should constitute an efficient and practical decision support in industrial, cross-functional teams."

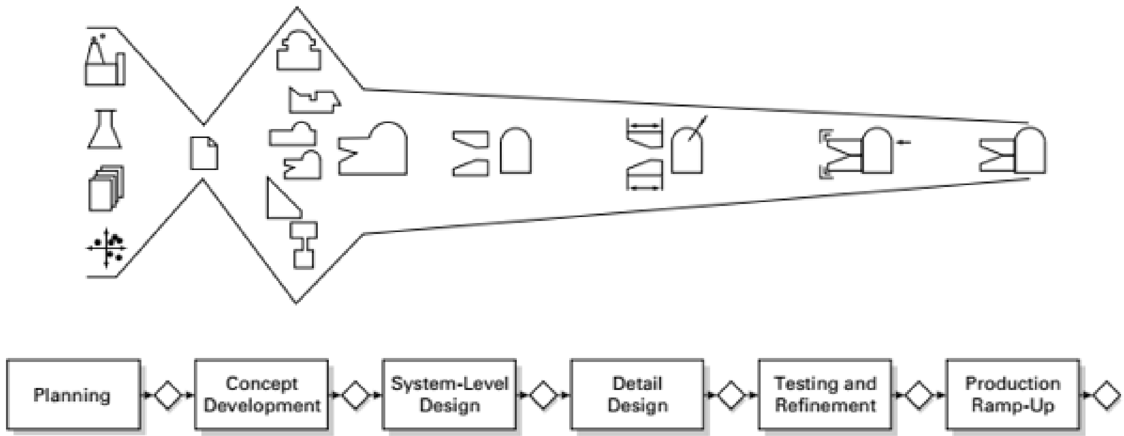


Figure 1.1: The product development process showing the process in a basic overview [33].

In the next part of this section the importance of each goal is determined in a chronological order where each goal presented above is clarified through their respective possible benefits and achievements.

In the "Concept Development"-phase many alternative concepts are generated and evaluated [33]. This phase is acting within a space where knowledge about the problem is low [34], shown in figure 1.2. On the left side of the figure it is visible that the knowledge about the problem is low, but as time progresses the knowledge increases, as seen on the right side of the figure. This means that the information is vague in the beginning but at the same time the design freedom is at its highest at the beginning. This results in a bad balance since the design freedom should be used to its fullest in the beginning to reduce costly changes towards the end. This was one of the goals that, according to Almefelt(2005), the BWS-process is aimed towards. It is aimed to enable teams to develop concepts even when the information is low meaning that it would fully enable the team to use the design freedom to its fullest potential.

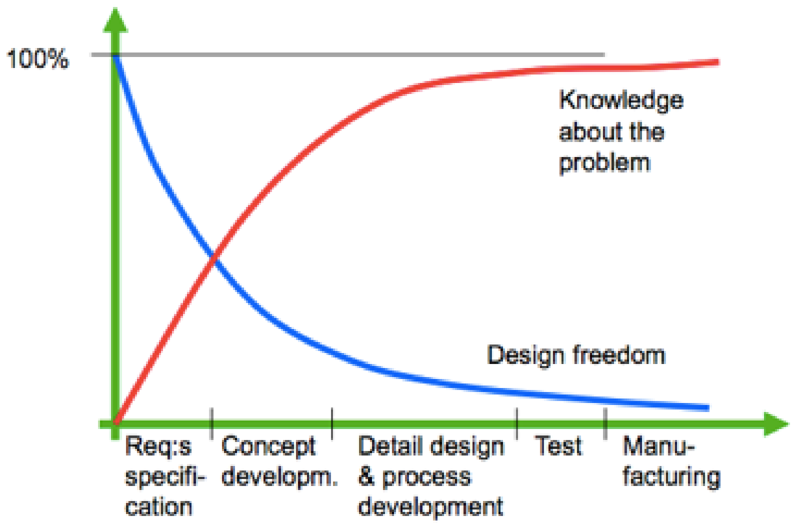


Figure 1.2: The interaction between knowledge increase and design freedom decrease as project time progresses [34].

Moving on, it is important to have cross functional teams within projects. This is something that Wheelwright and Clark (1992) emphasize. What this means is different parts of for example, a project team, work together with rich information exchange. An example would be design engineers informing engineers at production that a certain product will require certain production processes and based on this information they can prepare or give feedback, this is concurrent engineering. The benefits from cross functional teams are immense and this is what the BWS-process allows through incorporating rich communication within activities involving different competences. Some of the benefits with cross functional teams are: coping with unexpected changes, downstream capabilities, quick problem solving and error-free design. This is illustrated through figure 1.3. The white boxes are "phase of engineering activity" and the arrows are communication arrows showing the direction. For example, model 1 known as batch communication or over the wall-processes leads to longer lead times compared to model 4 which shows that intensive communication leads to shorter lead times. This all comes together to improve the "Time to market" profits. According to Wheelwright and Clark (1992), introducing a product six months ahead of competitors can triple the total profit over the total product life cycle.

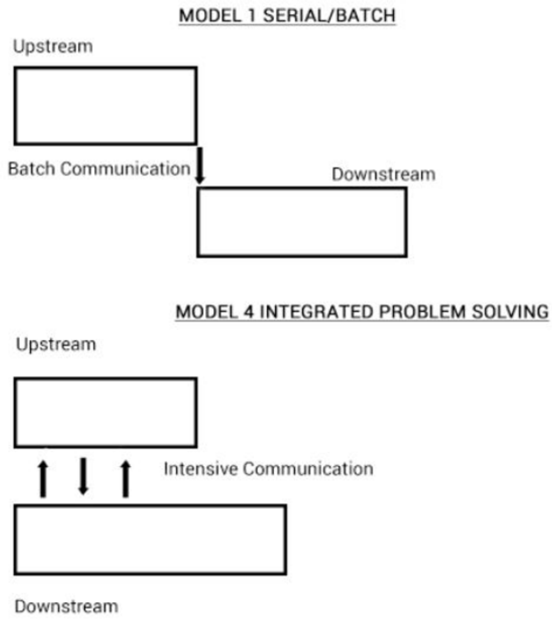


Figure 1.3: Simplified version of the four models of Upstream/Downstream interaction [37].

The two last goals of the BWS-process are: correlation in regards to the benefits and why they are important. Synergies or balancing are important because of how different sub-solutions interact differently with each other. Sub-solutions are easily isolated while developing a product, this means that sub-solutions lose the relationship with the overall concept solution. Moreover, there may be a higher risk of conflict between sub-solutions if the relationships and interaction are examined. This could result in loops, which will require additional time and cost. Balance between sub-solutions can be illustrated with an example: A bottle of wine may be very expensive and it may go very well with a piece of entrecôte, but when dealing with a sub-solution that in this case would be a Big Mac meal, the bottle of wine may not have good synergies with this particular dish. Therefore there exists, by the activity of balancing while synthesizing, the possibility to achieve a better synergy with the introduction of Coca Cola as a sub-solution. Even though the wine may be of an expensive brand (and on its own be excellent) it will never achieve the synergy that the Big Mac and the Coca Cola may have. And to tie this with the last goal, the performance/cost-ratio, a higher ratio can be achieved by the described synergy between the sub-solutions being Coca Cola and Big Mac instead of wine and Big Mac.

1.2 Project Scope

The goal of the project is to, through method development, enhance the "Balancing While Synthesizing"-process. In this project the method development entails a redesign of a step in the process and a digitalization of the overall process.

1.2.1 Problem Definition and Objectives

The BWS-process has been part of two major studies with promising results regarding both how the users experience the process and the outcome itself. The studies also showed opportunities of improvement regarding a step in the process where users experienced the step as being less intuitive and difficult to understand. In some cases the users even skipped this particular step completely while working within the BWS-process. This step is called the "Functions Balancing"-step (the fourth step in the process) and is described in detail in section 3.0.2.3. The first objective of this project therefore became to focus on how to make the step more intuitive by first finding the underlying reason, and then improving the process through method development. Moreover, while conducting a method development project it would be of importance to incorporate further ways to improve the BWS-process. One way to further improve the tool would be by digitalizing the BWS-process and possibly achieving an overall improvement, thereby resulting in the second objective.

1.2.1.1 Objectives in Detail

The objectives here are aimed to drive a common theme through this master thesis and are divided into two parts as stated in the previous sub-section. The two parts are: "In process"-outputs (what the BWS-process directly does) and the “External"-outputs (what the BWS-process produces).

The "In process"-outputs:
- An improvement to the "Functions Balancing"-step
- A digital version of the BWS-process, i.e. a software that through the previous improvement in combination with a new medium can provide even further benefits such as less tedious paperwork and faster visual results.

The “External"-outputs:
A tool which is:
- Resource effective
- Easier to learn
- Easier to use
- Assessing synergies between sub-solutions
- Producing innovative concepts
- Encouraging interdisciplinary networking activities

1.2.2 Limitations

This master thesis is conducted by a single masters student, which resulted in a need for limitations. If the limitations did not exist the project would not be feasible.
Literature study:
- The literature study will not research all the different human interaction and cognition topics that exist.
- In this project it is not feasible to conduct direct customer research since the

past cases where end users were engaged with the BWS-process were carried out several years ago. This means that contacting past users would not result in good quality data since the time that has elapsed could cause discrepancy regarding how the users would recall their interaction with the BWS-process.
• Studies of how other digital software work was not made.
Digitalization:
• The project will use an existing software package which will have its own benefits and negative aspects.
• No new programming language (example: Java, C++) will be learned for solving this project.
• The goal is not to make a complete finished software package but rather a working product. This means that the digitalization is limited to basic functionality and for example fully dynamic factors are not present.
Outcome:
• No further development or impact study will be done in this project, the reason is that there simply is not enough remaining time within the allocated space for the master thesis project.

1.2.3 Actors and Stakeholders

- Industries with new product development projects (The automotive industry etc.)
- Product developers
- Examiner/Supervisor - Lars Almefelt
- Student - Dennis Noubarpour

1.2.4 Expected Outcome

- Design and planning material for the digitalization part
- A digital version of a new "Balancing While Synthesizing"-process
- Different concept for solving the "Functions Balancing"-step
- Analysis of past user interaction research
- A needs list
- Academic paper on the topic

2

Theory

The theory study was conducted to gain fundamental understanding about the master thesis objectives. The study also aims to support decision-making and generate solutions. The main areas in the theoretical study were: The product development process and the field of interaction design. The figure 2.1 displays the connection between the main areas and the BWS-process as well as the main areas and the objectives in the master thesis. The circles represent how the theoretical studies both interact with the BWS-process. The squares in the figure represent the objectives in the master thesis.

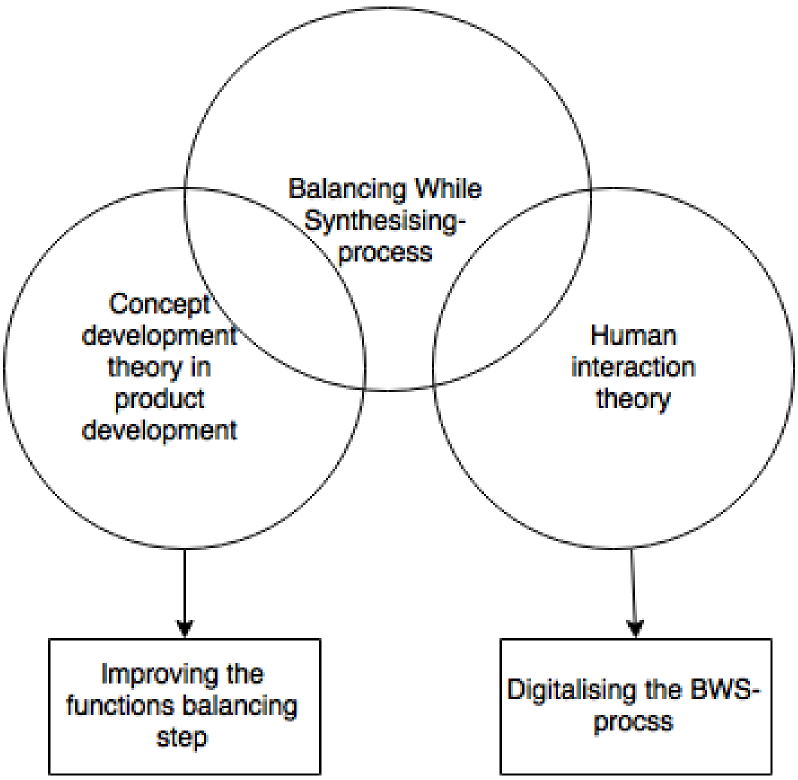


Figure 2.1: The theoretical connection to the objectives in this master thesis

2.1 The Product Development Process with Focus on the "Concepts Development"-Phase

This section focuses on general theory regarding product development, the concept development within product development which builds a theoretical base. This base enables a more narrow and focused theory study to be built upon. This additive process is displayed through the figure 2.2, which consists of three parts. One can argue that the BWS-process is connected to all the parts of the triangle in figure 2.2, thus explaining the shape. Where each section of the triangle narrows down more towards the objective of improving the functions balancing step. The subsections below are structured in the same fashion as the triangle, in a chronological order starting with the base of the triangle and going upwards.

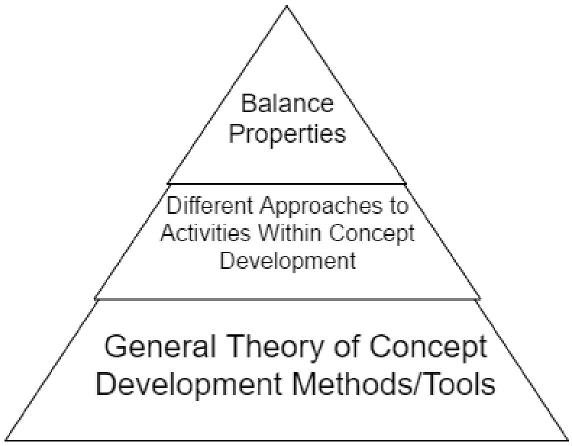


Figure 2.2: Triangle showing the theory framework (more narrow focus on the objective higher in the triangle).

2.1.1 Theoretical Framework of Concept Development

This section is divided into two parts; concept development in general and the different approaches of concept development.

2.1.1.1 General Background About Concept Development Within Product Development

Concept development may demand the most coordination among different parts within an organization according to Ulrich and Eppinger (1995). Concept development in product development can be seen from different aspects:

1. Knowledge creation [18]
2. Product design [12]
3. And especially, in new product concepts, it is a big part of the final goal itself [10]

The concept development can be seen as a process with different steps, this being obvious while studying different concept development methods, see the subsections

2.1.1.2 below this section. The concept development processes are divided into smaller steps.

2.1.1.2 "Concept Development"-Methods

As defined in this report (seen in the "Terminology"-section within the frontmatter) a concept is a set of functions and their solution that make up a possible system solution for a product. A seven step approach towards concept development was created by Pahl and Beitz (1995) presented in figure 2.3. This approach contains the steps being: Information, Definition, Creation, Evaluation and Decision. Here it can also be seen that the conceptual space is made up by several steps starting with identifying the essential problem and ending with an evaluation with different criteria.

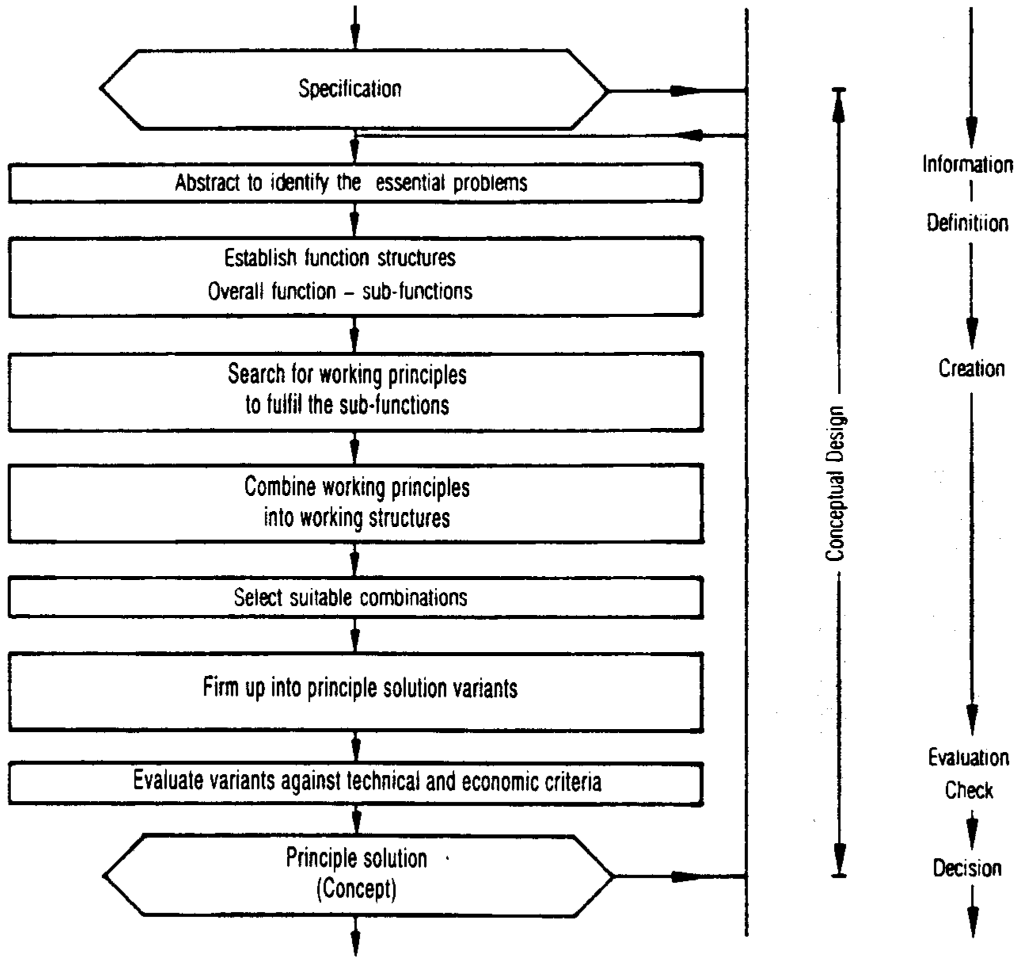


Figure 2.3: Steps of conceptual design. [27]

Ulrich and Eppinger argues for a certain order of activities for concept development, the activities are shown in figure 2.4. They call it the "front-end process" and it consists of iterative activities. The front end process rarely acts in a sequential fashion according to Ulrich and Eppinger. The output from each step is

Concept generation, Concept selection, Concept testing, Setting final specification, Project planning, Economic analysis, Benchmarking of competitive products and Prototyping.

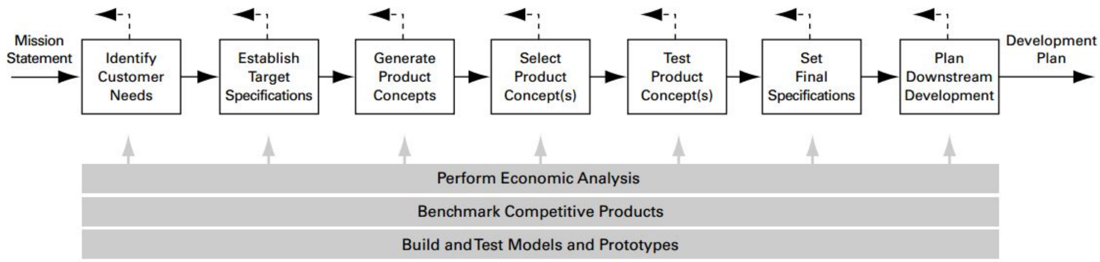


Figure 2.4: Activities of concept development according to Ulrich and Eppinger

2.1.1.3 Different Approaches to Activities Within Concept Development

The following subsections in this section are divided into two parts according to the concept development process presented by Ulrich and Eppinger (1995), figure 2.4. The focus of the sections are "Generate Product Concepts" and "Select Product Concepts" as these areas directly correlate to where the BWS-process is being used.

2.1.1.4 Generate Product Concepts

Pugh (1990) presented a checklist with major specification elements for product design specification. These elements can be used as a checklist for designing and creating a product. For example, when creating a concept, the checklist is worked through to examine if the concept passes through the criteria.

Shah (1998) classified idea generation methods in a structure idea generation classification. Idea generation is divided into two groups, see figure 2.5, intuitive idea generation which aims to remove perceived barriers and logical idea generation which step by step analyses the problem and generates ideas by decomposition.

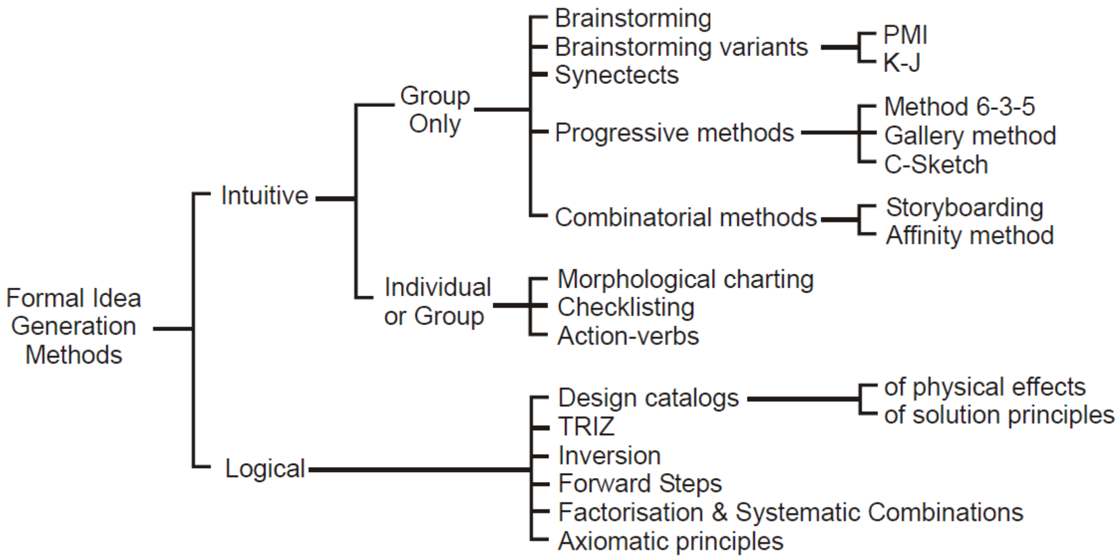


Figure 2.5: Classification of idea generation methods according to Shah (1998)

C-K theory or Concept-Knowledge theory was initially developed in 1996 [24]. This design theory is used between two so called spaces, a concept space and a knowledge space. Concept space is where propositions of no logical status are made. Knowledge space is where logic and past knowledge in different areas are presented. Some unique attributes of the C-K theory have made it overcome past limitations: 1) It offers clear and precise definition of design and independent of domain. 2) It presents a theory where creative thinking and innovation is a central core. The tool was created from practical difficulties and was meant to support teams in highly innovative design projects. Figure 2.6 shows the interaction between the two spaces which is of importance. The interaction is called the design square and it shows how the concept space expansion is dependent on knowledge and that the expansion is knowledge dependent. Exemplifying a C-K design square: Gather classic knowledge called K1. Let this knowledge expand the first set of concepts through partition and validation (going from knowledge to concept is called disjunction). Resulting in a path of innovation generated in the concept space. The concept leads discovery and experiments which create new knowledge. This makes it possible to go back to the knowledge space. The knowledge base expands and makes it possible to form new concepts.

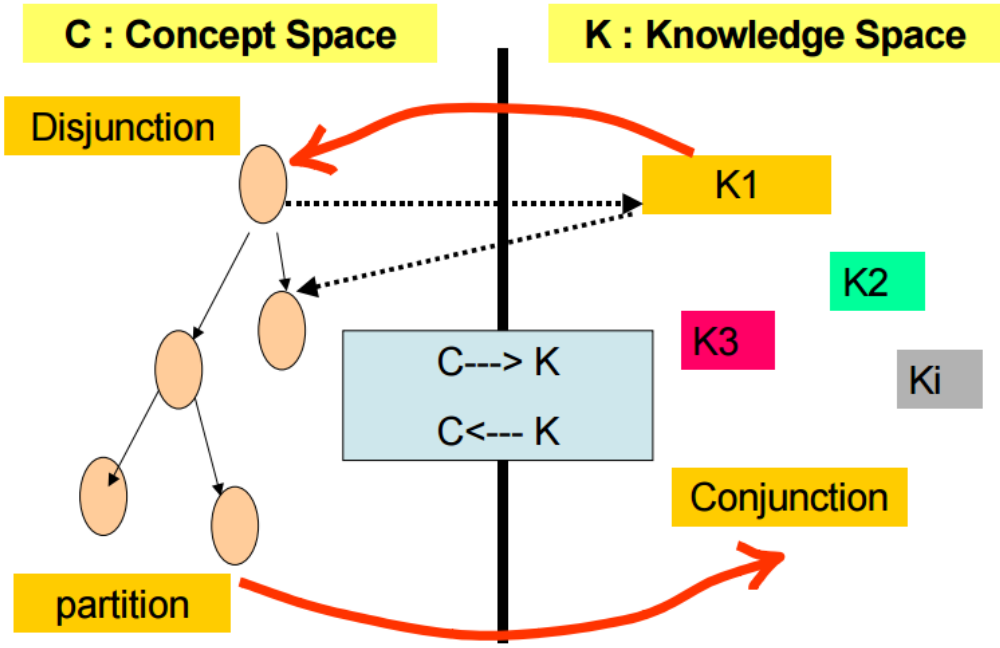


Figure 2.6: This figure shows the dynamics between the Concept space and the Knowledge space [25]

2.1.1.5 Select Product Concepts

The morphological matrix [39] is a matrix which contains alternative solution proposals on a horizontal level(rows of the matrix) and functions on a vertical level(columns of the matrix). The point of creating a morphological matrix is to easily create different concepts by picking one solution from each row. By picking another solution for a function, another concept is created. This process of picking and matching different solutions makes it possible to create a very large number of concepts in a short time while keeping a structured work-flow.

One method of screening concepts is the Kesselrings evaluation method (1951). This method compares concepts with each other and assigns a score according to how well a concept accomplishes requirements or the objectives of the project goal. Another screening method is the Pugh (1990) evaluation method which compares concepts with each other as reference with the same technique of assigning scores. The inferior concepts are then removed and another reference concept is set and the process of comparing and scoring is repeated. Elimination matrices can also be used for screening concept solutions Pahl, G. Beitz, W., (1996) where solutions are given scores. One for passing a specific requirement and, one for failing a requirement. In this way unfeasible concepts can be eliminated quickly.

2.1.2 Balancing Properties

One of the core concepts of this master thesis is the concept of balance. In this section the definition and alternative methods are presented.

Balancing according to the Swedish academic wordbook is defined as equilibrium. This is a more general description of the word and not put in context to what the word means in this master thesis. The word here refers to providing user value by managing properties of concepts in a cost-efficient way. The property balancing act also referred to as the synergy assessment was exemplified in the section 1.1.1, referring back to the example of how Coca Cola yields higher user value in comparison with the more expensive wine.

The figure 2.7 shows different balancing properties tools with their respective drawback. The purpose of this image is to show which tools exist in the first place, but also why their balancing methods are flawed.

TOOLS SUPPORTING BALANCING ACTIVITIES:	Drawback:
Value Analysis:	Very resource-consuming and do not explicitly consider interrelationships in the concept
Pugh's concept evaluation and enhancement method	Very resource-consuming and do not explicitly consider interrelationships in the concept
DSM technique	Requires a lot of information to be available initially
Hansen model	No focus on a practical work procedure for cross-functional teams
SOS (Subjective Objective System)-method	The model has to be fed with detailed engineering data.
DSO (Direct Synthesis Optimisation)	Don't actually focus on utilising synergies

Figure 2.7: Balancing tools with their respective drawback (inspired by Lars Almefelt (2005).

2.2 Interaction Design Theory With Focus on Methods and Tools Development

The following section is divided as; the background of interaction design followed by the process of interactions design and finally the goals and design principles of interaction design.

2.2.1 Interaction Design Background

The definition of interaction design can be described by: designing products that support people in communication and interaction with their everyday and working lives [21]. Winograd defined the word as designing space for human communication and interaction [36]. As the definitions imply the practice is focused very much on how to design user experience using a range of methods, techniques and frameworks. The term interaction design was first coined by Bill Moggride And Bill Verplank in the mid-1980s . Moggride describes his first description of the subject as: "I gave my first conference presentation on the subject in 1984, and at that time I described it as "Soft-face," thinking of a combination between software and user-interface design...we went on thinking of possible names until I eventually settled on "interaction design" with the help of Verplank" [17]. Lately, there have been more perspectives introduced to the field of interaction design, Cooper and Reiman emphasises interaction design to be more "goal-oriented" [7]. Lowgren and Stolterman on the other hand focuses more on the perspective of "thoughtful"[16].

Interaction design can be divided up in many parts such as Academic principles (ergonomics, computer science, psychology and informatics) Design Practices (graphical design and artist-design) and Human-Computer interaction. These parts span across many different fields and disciplines [21].

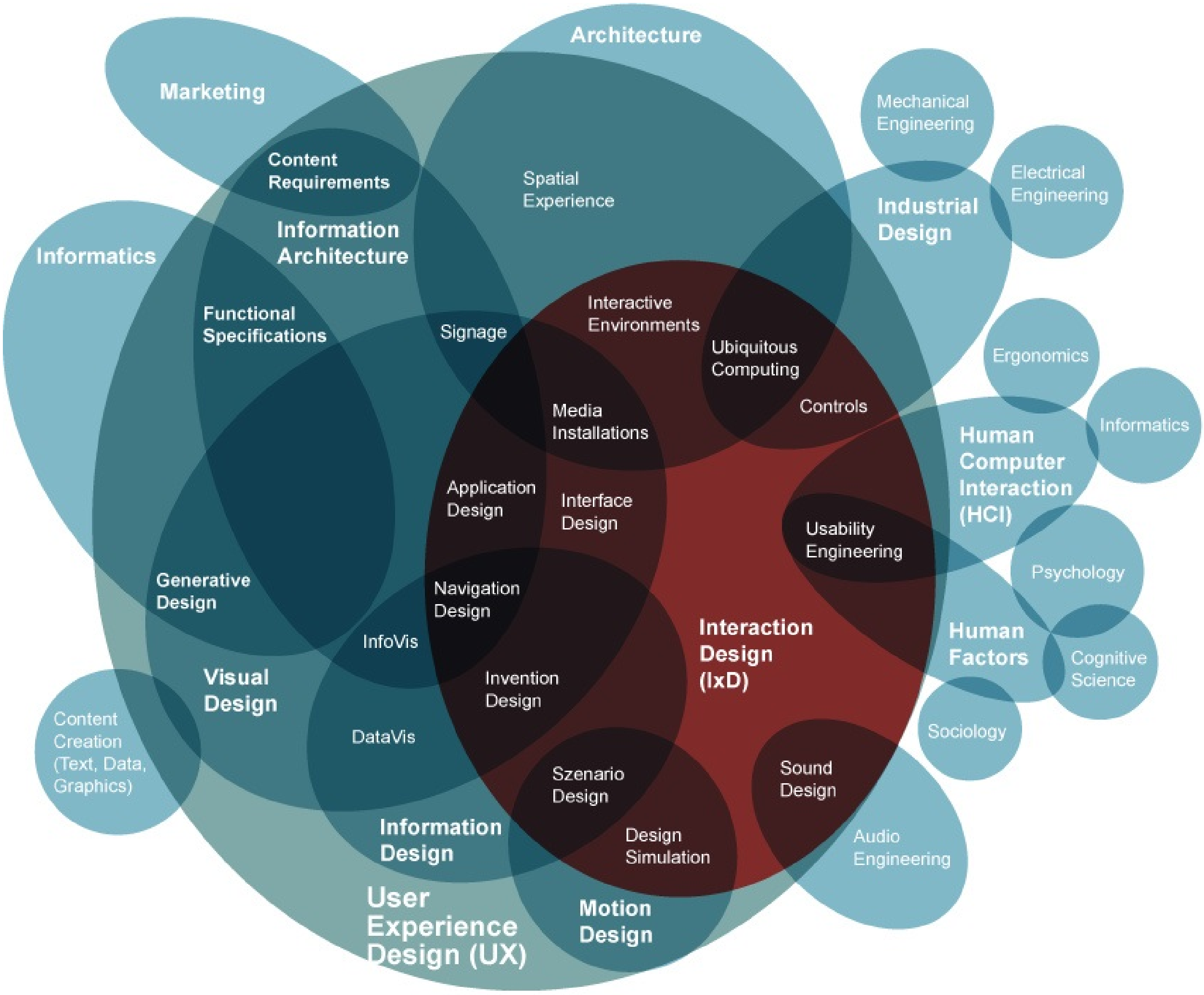


Figure 2.8: The many fields (and their interaction) within interaction design [32].

2.2.2 Interaction Design Processes

Copper and Reiman's "goal-oriented" design contains the following steps: 1) Research, which contains observation and contextual interviews with the creation of usage patterns. 2) Modeling, where the result from step 1 is synthesised into domain (information flow and work flow diagram) and user models. 3) Requirements step which outputs a requirements definition from step 1 and 2. 4) Framework definition where teams synthesise an interaction framework by working with two methodological tools (interaction design principles and interaction design patterns). 5) Refinement is the last step where validation scenarios and key paths (walk through) are used [7].

Preece et al. presents the process of interaction design as: 1) identifying needs and establishing requirements for user experience. To be able to keep focus on the users targets needs to be established. 2) Developing alternative design that meets those requirements. A core activity which contains conceptual design (model for the product) and physical design (what the product should do). 3) Building interactive versions of the design so that they can be communicated and assessed. 4) Evaluation that is being built through the process and the user experience it offers [21].

2.2.3 Goals and Design Principles of Interaction Design

This section is divided into three parts: two parts concerning user goals and one part concerning the design principles of interaction design.

2.2.3.1 Usability Goals

When something is regarded as easy to learn, effective to use and enjoyable, it is regarded as something with good usability. The purpose of usability goals is to present interaction designers with concrete means of assessing user experiences. Usability goals are broken down as follows:

- Effective to use (how good the product is doing what it is supposed to do
- Efficient to use (how well the product supports users to carry out their task)
- Safe to use (protects users from dangerous conditions)
- Having good utility (how well the product offers the right functionality)
- Easy to learn (time needed to learn about the product)
- Easy to remember how to use (once the product is taught, how easy it is to remember)

These are answered in an objective way since the assessment regards how useful the product is from its own perspective. The way to assess the usability goals is to conduct a questionnaire to evaluate how well these criteria are fulfilled which could even alert designers in early stages. The questions need to be asked in a detailed way to capture the problem [21].

2.2.3.2 User Experience Goals

User Experience goals are subjective qualities since they deal with how the product or system feels to a user. These could for example be: satisfying, enjoyable, fun, annoying, boring, motivating etc. These are just like usability goals, best evaluated by asking questions. By asking questions designers can become more aware of the chaining nature regarding the users experience, thus yielding a better understanding and develop user experience goals. [21].

2.2.3.3 Design Principles of Interaction Design

The design principles are a mix of theory-based, knowledge based, experience and common sense [21]. Feedback is a term commonly used within this subject: Users should know what to do next by the design of the product. Other terms used in the subject of design principles are: 1) Visibility - knobs and buttons are highly visible. Users know what to do to make the product work. 2) Consistency - restricting users interaction in a given time, for example making options unavailable when they are unnecessary. 3) Affordance - using the same elements for tasks of similar activities. For example if a red button makes a ball bounce, use a red button for making something else bounce. 4) Affordability - the element itself gives the user an idea or a clue of what to do with it. For example, user knows that buttons are meant to be pushed. While applying these design principles it is important to be aware of the trade off element, concentrating on one element could mean that other elements are in risk of being affected in a negative way.[19].

2.2.3.4 Interaction Design With the Focus on Learning and Visual Design

Peters view of interaction design is more angled towards learning and cognition. Peters argues as well for the importance of the design principles and adds that "Poor Interface design can get in the way of learning by slowing it down, imposing hurdles and using precious cognitive load." The cognitive load is of importance since the more a user allocates to the interface, the less is available for learning. Colors can be used as a very effective tool for interface design. It's been shown to support learning as well as understanding tasks. Colors enhance engagement and the effectiveness of the visuals presented in the interface. There are more tools for making our brains target the visual features unconsciously. These are: 1) orientation, 2) bigger size can be used so size equals different steps in a hierarchy, 3) direction, for example things placed at the top of a screen are considered more important than things lower down, 4) depth can also imply hierarchy in a visual way where objects in the foreground compared to the background are seen as more important. Peters states that research has shown that these pop-out features are recognized in less than one-tenth of a second, confirming the pop-up features power. But these should be used with caution since overuse results in overwhelming the brain and returns a negative effect. Colors can also be used to imply hierarchy, in this context the color itself does not imply the hierarchy (for example red before blue) but the saturation does (for example a stronger red color compared to a pale red color) [30]. Ruth Clark and Chopeta Lyon outlined a five-phase iterative method for visual design: 1) Define the goal. 2) Determine the context. 3) Design the visual approach 4) Identify communication functions of visuals to match content types. 5) Apply principles of psychological events to visual design decisions [15].

2.3 Conclusion of the Theory

The theoretical chapter has presented, just as figure 2.1 stated, a background which was focused on the objectives and relevant to the scope. It can be concluded that the concept development methodologies share similarities with each other when comparing the "Pugh and Beitz"-approach and "Ulrish and Eppingers"-method. It is again noteworthy that the later method is a more iterative approach compared to the linear "Pugh and Beitz"-approach. These also share similarities with the BWS-process since they have a planning step which could be a parallel to the first step in the BWS-process. They also have a step which expands upon solutions, just like the second and third steps of the BWS-process and an evaluation step similar to the "Functions Balancing"-step.

When looking at the different concept generation methods, the CK-theory is more targeted towards new product development in comparison to the other concept generation methods presented in the theory section. The concept generation methods presented by Shah can arguably be used in new product development due to the flexibility. Shahs classification can also work when conducting idea generation for less novel product development. There are also similarities between concept development methods and the interaction design process although the interaction design is a more abstract level of design since it may be more grounded in subjective decisions compared to concept development within product development which is very dependant on objective decisions. An important outcome of the theoretical study is the interaction design guidelines and the visual guidelines. These two guidelines will arguably aid greatly towards the implementation of a digital BWS-process.

The interaction design theory conclusion is that the different steps to make successful design are very similar and the procedures are straight forward, constructed in several steps. The theory also presented usability goals and design principles which will be taken account for when proceeding with the project, specially when digitalizing the BWS-process.

3

Study of the "Balancing While Synthesizing"-Process Before Conducting the Master Thesis Project

This chapter represents one of the outcomes from the "understanding the problem" section (section 4.2.1) presented in the method chapter. This chapter breaks down the BWS-process and presents each step in the process.

3.0.1 Overview of the "Balancing While Synthesizing"-Process

The BWS-process overview is shown in 3.1. The process is divided into 5 steps, each step is described in the next section. The overview shows how an input parameter being "An assignment" becomes the output which is "A promising concept". In the subject of breaking down the process Almefelt (2005) says: “The method does not guarantee the ultimate concept, since all possible combinations are not studied, and factors not included in the method may affect the overall performance, but it produces an effective concept solution using minimal resources." A key note to take from the statement is that the process does not interpret all of the various possible solutions that may exist for a concept solution. This makes the process, in combination with sub-solution balancing assessment, a viable process for concept and product development with vague information.

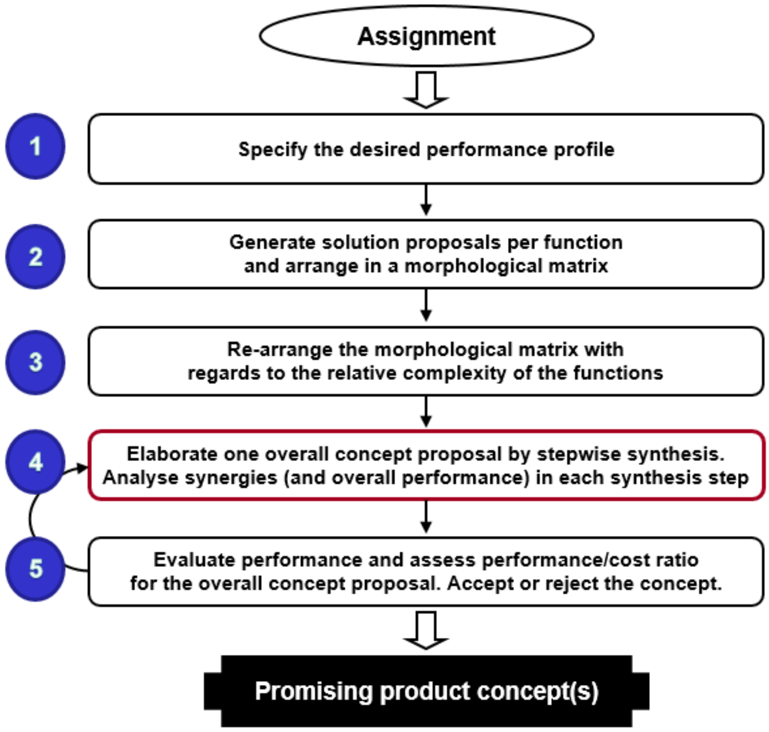


Figure 3.1: The "Balancing While Synthesising"-process overview based on Almefelt(2005) [1]. The "Functions Balancing"-Step, step 4, is marked in red.

3.0.2 Description of Individual Steps in the "Balancing While Synthesizing"-Process

This section explains how the BWS-process prior to the method development project is constructed. This sub-section is, as presented in figure 3.1, broken down into five steps.

3.0.2.1 Step 1: Setting up a Performance Profile

The first step in the BWS-process is to make a performance profile, see figure 5. Performances in this case refers to what the system is or wishes to be. Each performance affects the profile in two ways. The weights (W1,W2 etc.) along the y-axis and their length in the performance-axis (x-axis). Each function also needs 4 parameters defined (on the performance-axis):

- Where the industry average is, compared to the ideal performance (5 on the scale)
- Where the performance is today (the blue dotted line)
- What the lowest acceptable performance is (the red dotted line)
- Where the goal for the performance should be (the end of the bar)

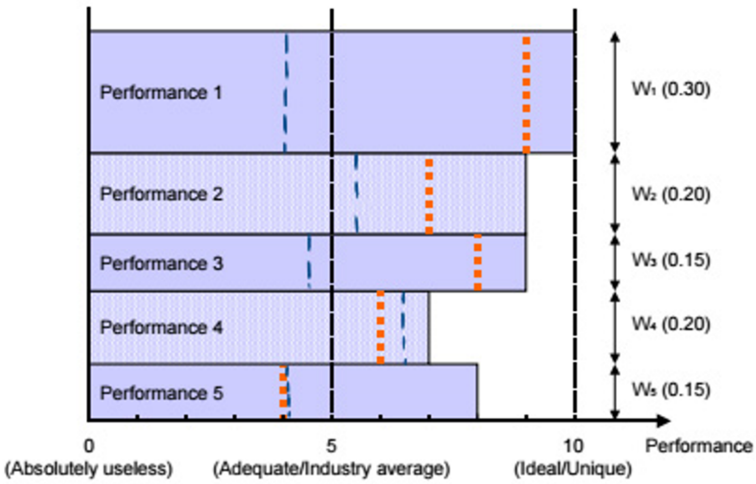


Figure 3.2: The Performance Profile (adapted by Almefelt, 2005) [1]

3.0.2.2 Steps 2 and 3: Creating a Morphological Matrix and Rearranging Functions

The next step is to make a make a morphological matrix, [39] this means that users need to generate different solutions for a function, see figure 3.3.The functions with the most interaction with other functions are placed at the top. Almefelt says this about the order of the functions: [“In order to maximise the potential for a concept synthesis utilising synergies, the morphological matrix is re-arranged with regards to the relative complexity of the functions. . .]”. The most interesting combinations of sub-functions are then added together from the morphological matrix to form a concept, this is shown by the red arrows in figure 3.3.

3.0.2.3 Step 4: The "Functions Balancing"-Step

Next is the balancing-step, where users evaluate each sub-functions synergy by the activity of balancing while synthesizing. In this report the name of the balancing synthesis is chosen to be functions balancing step. While conducting each synergy step users need to keep four aspects in mind. Firstly all the performances stated in the Performance profile in the previous step. Secondly engineering aspects: Performance, Geometry (manufacturing) and the Materials. While having these four factors of balancing in mind each function is then evaluated step by step, see the red arrows in figure 3.4. Each step combines the current sub-functions and adds up towards the evaluation of the function below, which is shown in 3.4. Each step also requires a grading of how well the synergy is between the compared function and the sum before.

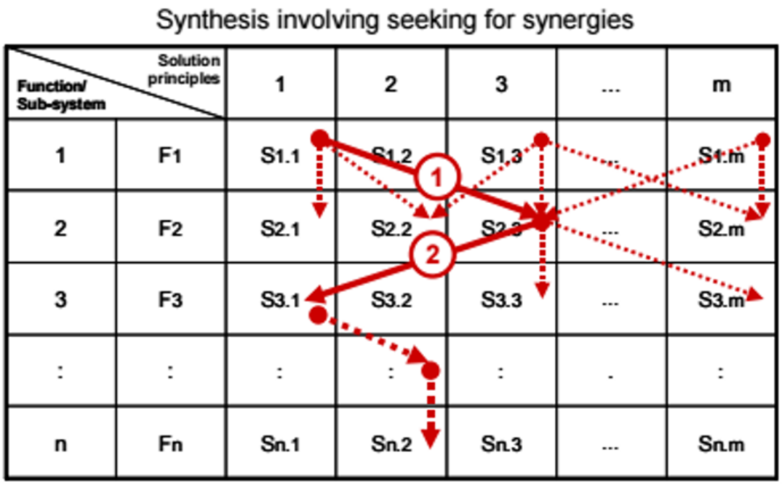


Figure 3.3: Stepwise assessing a concept while evaluating synergies [1].

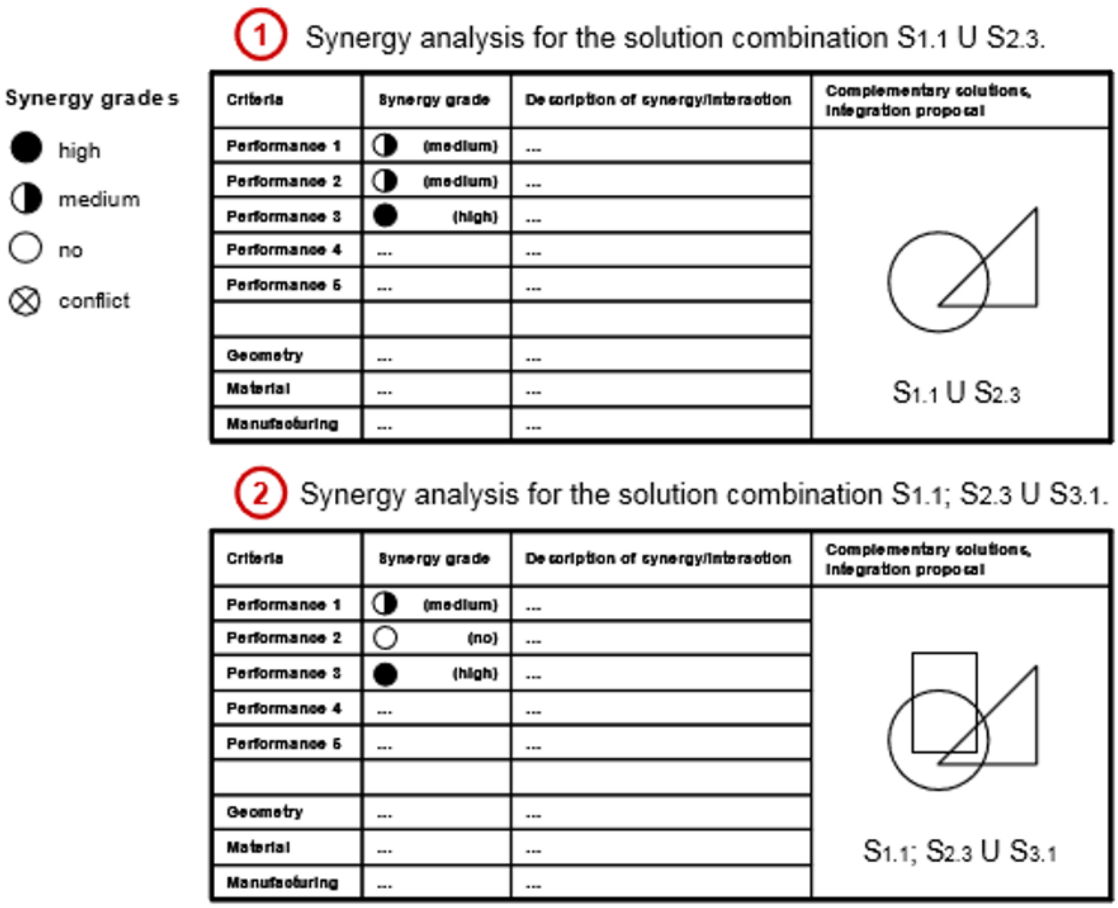


Figure 3.4: Functions balancing step [1].

3.0.2.4 Step 5: Evaluation

After the synthesis is done, The performances of the concept are then put in to the old performance profile and as figure 3.5 shows it generates, by adding the weights and their grades, an overall weight performance [27]. This is then divided with the estimated cost for realizing the product and then entered in a performance/cost-plot, seen on the right side of figure 3.5. If the result is not desirable an iteration process can be started from step 3 where a new combination of sub-solutions are picked and then carrying out the same steps to achieve a new performance/cost-ratio.

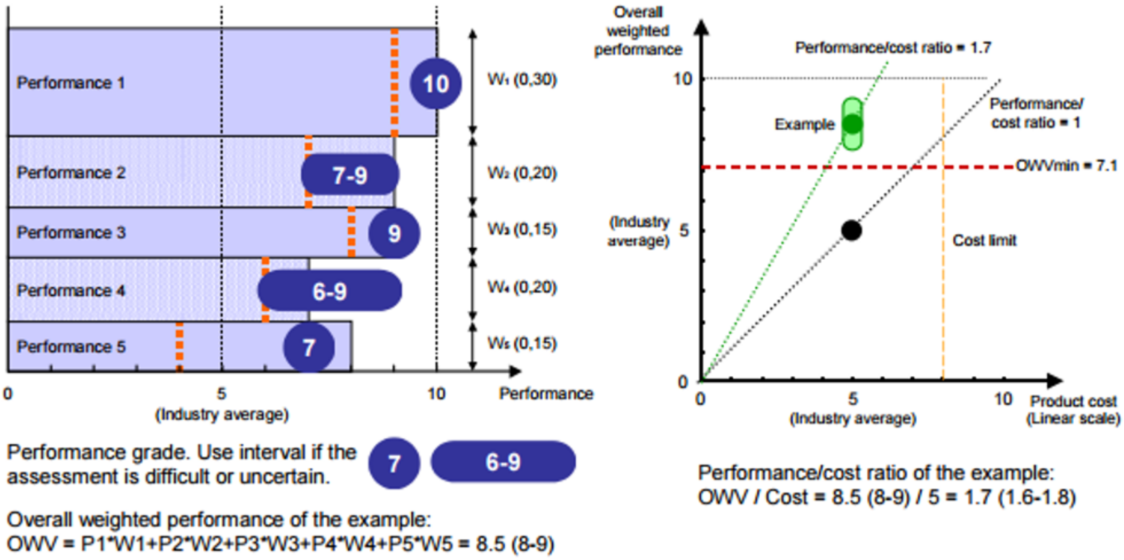


Figure 3.5: Performance profile (left figure) and Performance/Cost-ratio (right figure) [1].

4

Methodological Approach for the Master Thesis Project

The approach of this master thesis will be divided into two parts correlating to the two big objectives this project is based on. To clarify the main objectives again; improving the "Functions Balancing"-step and digitalizing the process. This means that the method is divided into two major steps for solving the two different objectives. These objectives can't be worked upon completely in conjunction since the improved "Functions Balancing"-step needs to be completed so the updated version is then implemented in the software package.

4.1 General Development Approach

The overview of the method in general is presented in figure 4.1 below. This figure shows the basic steps of the method. The first step is to understand the problem, since it is already an existing tool it needs to be broken down to understand the problems. The next step is the subject of chapters 2.1 and 2.2, the improvement of the "Functions Balancing"-step and the digitalizing of the process. These two parts combined become the method development. Then the next step is to conduct a case study and lastly to analyse the data which will be the outcome of the case study.

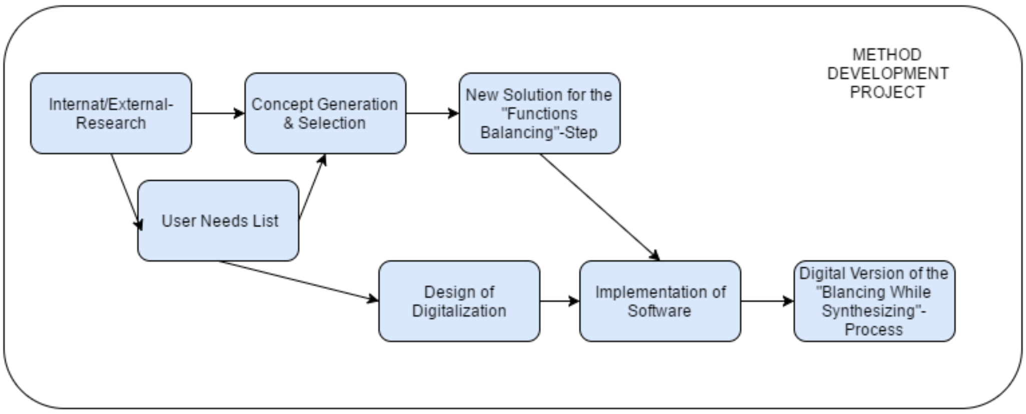


Figure 4.1: Basic overview of the complete project method. The figure starts from the left side and ends on the right side, just like the progression of the project.

4.2 The Method Used for Improving the "Functions Balancing"-Step

The method to find the best fitting solution concerning the improvement of the "Functions Balancing"-step is inspired by the Ulrich and Eppinger product development method [33], moreover the generic concept development method as it can be called. This means that this project will inherit steps from the Ulrich and Eppinger(1995) method but it will not follow it strictly. The reason is that this project does have a limitation regarding the time and resources resulting in focus on the most important parts by selecting and scaling down these parts as shown in figure 4.2. The project method for this section starts with an understanding of the objectives and the problems. After that,an internal and external search are combined to identify customer needs and form requirements. And lastly concepts are generated and the best concepts are selected by screening with a weighted needs list. The following chapters will analyse each part and further clarify the method.

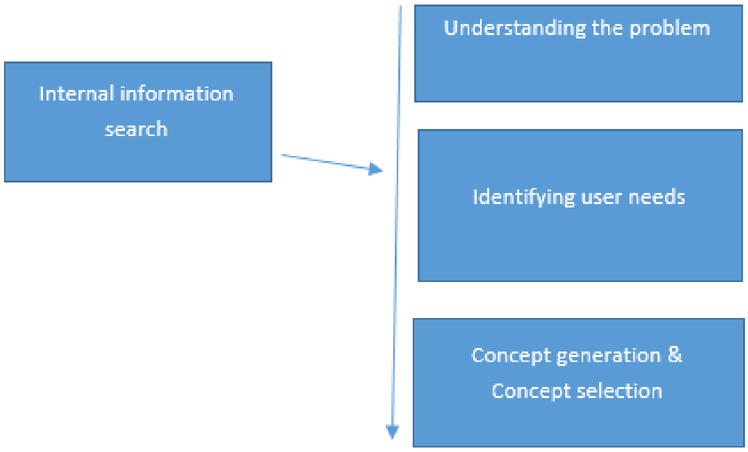


Figure 4.2: Overview of the "Functions Balancing"-step concept generation method.

4.2.1 Understanding the Problem

Usually products can be seen as closed systems, with inputs and outputs. A system in this case is made up of different functions, and within a "black box" acting as the systems boundaries. The functions are driving the input through the system until an output is present. Physical products, where functions are represented by different parts of the product, can be broken down in this way for better understanding of the interrelationships [27]. One of the advantages of setting up a function structure is that by having a clear definition of the functions, they can be dealt with separately. This approach was applied to the BWS-process. The five steps of the BWS-process were seen as different functions and were picked apart and investigated individually and as a whole. Arguably the overview image, figure 3.1, can be seen as a system with inputs and outputs. A conversion was made and the result is displayed in section 5.2.1. The approach made it possible to further flesh out relationships in the

"Functions Balancing"-step.

This step paved the way for easier planning of the digitalizing of the product since the planning phase basically consisted of recreating the BWS-process in a flowchart. Also, a better understanding was gained of the strength and weaknesses of the tool which are presented in section 5.1.1.2.

4.2.2 Identifying User and Software Needs

The goal with this step was to establish the users "wants" when using the BWS-process and what the software development needs were. The purpose was to form a list containing all the needs with different weights of each need. The method used to form the needs was to use two types of information searches as displayed in figure 4.2, an external search and an internal search. The subsections below present the methods for each information search.

4.2.2.1 Internal Search

The tool has been a part of two research projects. After the first research project, users gave feedback by answering interview questions. These interview documents were used as empirical data. The interview answers were stepwise reduced and similar statements were grouped together. This method was inspired by the KJ-method [14] as it was a lighter and simpler version. These groups were then condensed into one need which represented what the users wanted, this procedure was repeated for all the findings from the empirical data. The needs assessed from this method must be expressed in what the product has to do and not what it might do. This is in line with what Ulrich and Eppinger suggests as guidelines for conducting user needs.
The second research project was conducted on a large scale. The same procedure of interviewing users was used in this project as well. Although, the empirical data collected from this particular project was not as detailed as the older project. The answers were already condensed into one line answers, but the essence of the users response was still eminent.
The answers from the internal search were compiled at the end, i.e. the answers from both projects were combined together to form the internal search user needs.

The master thesis student also added needs specific to the digitalizing based on the user needs list. Visual documentation of the first research project was also studied, in the form of photos from when users worked through the whole BWS-process. The study of how users interacted when working with the process yielded further information and strengthened the future needs list creation.

4.2.2.2 External Search

The goal of the external search was to gain broad knowledge of areas that the internal search did not touch upon, thereby resulting in new user needs. This means that the external search had the purpose to find new valuable information from sources which were not directly connected to the BWS-process and the objectives within the project. This was performed by a literature study, researching similar product development tools (which resulted in Concept development methods section) and a search for other successful digitalizings of concept generation tools. The desired result was to fill knowledge gaps regarding subjects such as intuition, human interaction, the development of the digital version of the tool, as well as provide stimulation for the solutions idea generation phase.

4.2.2.3 Compiling the Information Into One List

The goal was as stated in the beginning of this section, to identify the user needs. After obtaining empirical data from the two different search areas it was time to combine these to one final list of user needs. All user needs were first listed in a document in no certain order. Then each need was grouped together under one theme with similar needs. The process is inspired by the needs list method from Ulrich and Eppinger (1995). After the grouping was done, weights were given to each need. The weights were given the numbers one to three: one was the lowest weighted need (a "want" that was in low demand), two a medium weighted need and three was a need that the users saw as critical. This also applied to needs that came from the the external search. These did not directly come from the end users but as they shared the same purpose later on, the purpose of picking the best solution, they were added to the same list of needs.

4.2.3 Generating A Broad Set of Ideas

Referring back to the theory study section 2.1.1.4 figure 2.5. The idea generation was done within the intuitive-classification amongst idea generation methods by conducting brainstorming sessions. The reason was that the problem was in a more abstract domain than for example a physical product development project. Because the project was conducted by one master thesis student the "group only' activities were naturally not able to be achieved. The method used was inspired by "Action-verbs" in combination with brainstorming sessions. Since there was only one student it was healthy to, after brainstorming sessions, take breaks spanning across a week. So that after resuming the brainstorming the the student could take a fresh look at ideas and continue brainstorming. In a sense, this simulated the brainstorming activities being conducted by a group.
Figure 5.2 in subsection 5.2.1 shows that the "Functions Balancing"-step is seen as a function within the BWS-process. This means that the idea generation process had the goal to generate a broad span of sub-solutions for the particular function within the BWS-process (the "Functions Balancing"-step). Questions were asked during the sessions to achieve different angles of attack towards the problem. These questions were:

- Making the "Functions Balancing"-step as simple as possible? - Easy to learn and easy to use.
- Showing as much of the process as possible for the users during usage of the balancing step? - Making the process as clear as possible and therefore achieve more

intuition.
• Changing the order of the process? - Achieve different possibilities to make the process more intuitive.
• Changing the BWS-process completely? - Achieve different possibilities to make the process more intuitive.
• Making the steps as rigid and "step wise" as possible? - Will this make the process less more intuitive?

Ideas were sketched and put on paper, with the philosophy that there should not be any critical thinking about ideas at this stage. As more ideas and solutions were generated, groups of different solution categories started to form. Solutions were then collected in these categories which is shown in the result chapter. This made it even further possible to achieve a broader perspective while generating ideas since they now needed to fill criteria to be apart of a category but still be different than the already developed ideas. This achieved the illusion of being forced by imaginary category barriers which yielded more creative thinking.

4.2.4 Selecting the Solution that Solves the "Functions Balancing"-Step In the Most User Intuitive Way

After a final needs specification was made, including weights for each need and solutions for the "Functions Balancing"-step, it was time to screen amongst the solutions. Since the needs list also included needs for the digitizing of the BWS-process, these were removed and saved for later when the actual digitizing needs were required. Each solution was put into the weighted needs list and scored according to how well it satisfied a need. The score was made up by numbers one to three: one was the lowest satisfaction, two a medium satisfied need and three was a fully satisfied need. A "0" was given if the solution was unrealisable or unfeasible. In the end when each need was scored the sum was calculated to give the solution its final verdict. When the process was done for each solution, four solutions were declared clear winners with one having the highest score. The scores were very similar between the three other solutions, and the decision to keep all four as final contestants going forward was made since it made sense not to neglect any high scored solution early on the project phase. The digitalizing was the next step in the project and naturally the information was low in the early stage of the process, as mentioned, this is displayed in figure 1.2. The method is inspired by lean development methodology and its "set-based concurrent engineering" which means: as late decisions as possible is of necessity [11]. The reason is because of that knowledge is lower in the beginning and a decision then would mean unnecessary iterations. Instead, to counteract this time waste the method recommends informed decisions later on within a process to save time.

4.3 Digitalizing the "Balancing While Synthesizing"-Process

This section presents the method of how the BWS-process was digitalized. The sub-sections are laid out in a chronological order following how the method was conducted.

4.3.1 Deciding the Digital Medium

The goal with this step was to find the most suitable software package for digitalizing the tool. The process was first started by finding software options and then evaluating them by a "Grading matrix". The grading was done by forming decision factors, factors which were important for the users and the developer of the digitalizing. The suggestions received grades according to: red is "unachievable", green is "acceptable" and yellow is "caution/need more information". By the end of the process a winner was decided by the amount of green grades.

4.3.2 The Method for Digitalizing the "Balancing While Synthesizing"-Process in this Master Thesis Project

There are many different methods for developing software. For example the Waterfall-model, the Spiral-model and Agile-development (iterative approach) [2] [8]. The Waterfall-model is a sequential approach [4] and the benefits are: easy to use and understand, widely used and known, and good for planning before implementing. The weaknesses for this model are: requires good knowledge of requirements, harder to backtrack since it is a linear process hence not preferred for complex projects. The Spiral-model has its own set of benefits: project monitoring is very easy and effective, early feedback from users indicates risks early. The weaknesses for the Spiral-model are: time consuming risk analysis, time spent on planning, project success depends on a good risk analysis. Finally Iterative development or Agile-development has its benefits: risk is spread across smaller increments instead of one big sprint, lessons are taught in each step and focus on important parts first. The weaknesses are: time consuming, requires good planning and no iteration within an increment [2].

The chosen method for this project is the Waterfall-method since it is simple to understand and easy to work with. The requirements for the project will be clearly defined as discussed in chapter 2.1.2. It is also suitable since it is used in less complex software development projects resonating well with the digitalizing of the BWS-process. The other methods were neglected since they require more time and are more complex which is not feasible for the scope of this project. The general Waterfall-model is displayed in figure 4.3. For this project it will be, for feasibility and scope purposes, scaled down to a smaller version shown in figure 4.4 in this report this smaller version is called the "Applied Waterfall"-model.

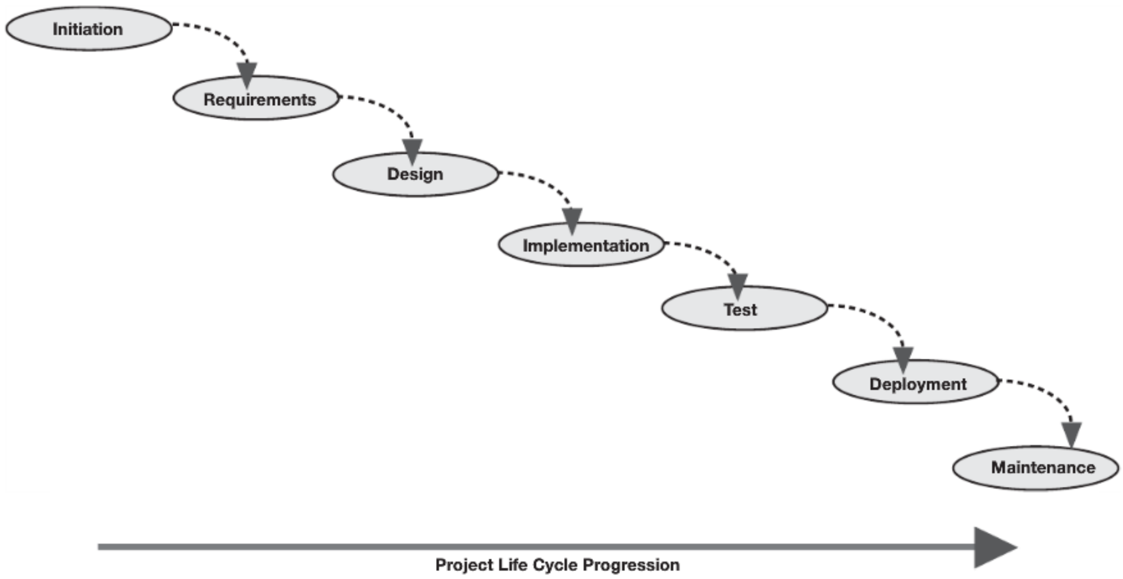


Figure 4.3: Overview of the waterfall-model[4].

The "Applied Waterfall"-model consisted of four steps, as seen in figure 4.3.2. The steps in the method did not require the same amount of time to conduct, something which the figure does not show. For example, the requirements step was already done in section 4.2.2.3, although it required a small alteration. The design and implementation steps resulted in the largest parts of the report even though the requirements and test steps were equally important. The following subsections will go through the method for each step of the "Applied Waterfall"-model.

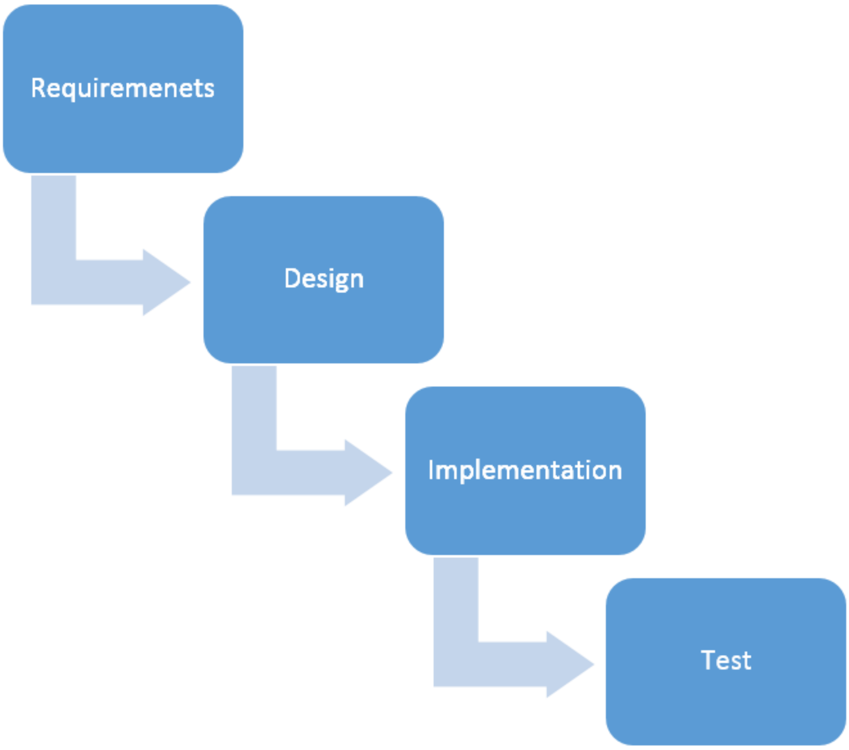


Figure 4.4: The "Applied Waterfall"-model inspired by figure 4.3.

4.3.2.1 Requirements for the "Balancing While Synthesizing"-Process Digitalizing

The goal with the digitalizing was to enhance the user experience. This means that the users needs have to be satisfied and kept in the center of the process, i.e. user need focus. The focus reflects on the requirements of the digitization since it is the first step of the process which the future steps are built upon. This was also found important from the section 2.2.2 when it comes to interaction design requirements. The needs list from section 4.2.2.3 was used in this stage as well, this time without the delimitation's of digitization needs. The list acted as a foundation of constraint and guideline for the development and worked in conjunction with the design principles for interaction design from section 2.2.3.3. This placed the focus of the development for the upcoming design step in the right direction.

4.3.2.2 Design Steps of the Digitalizing

The process of the design step is visualised in figure 4.5 where the goal is to design the process according to the BWS-process and the requirements from the past step also keeping the design principles from 2.2.2 in mind. When the final design was made a structure and framework was set for the implementation stage, being the desired result. The design step was made mainly in conjunction with the visual input and logic design. This can be seen in figure 4.5 where the green boxes represent input to the design process, leading into the white box in the figure. The visual design started out with rough sketches made with pencil on paper with guidelines heavily influenced by the design principles and the visual guidelines. The result from the visual design can be seen in the section 5. The visual design was also inspired by the STRATEGO-tool [35], a manufacturing strategy tool realized in Microsoft Excel. Not only because it was made in Excel but also since it had some elements that suited the design principles although improvement was made to further strengthen the design principles. The visual design was made for the whole software package, by first constructing a basic design framework and then basing further designs on the framework.

The logic design was made up by constructing flowcharts which represented the logic flow and the structure of how each part of the BWS-process should be constructed in the implementation phase. A flowchart is a diagram which shows algorithms, workflow or processes represented by various figures ordered by connection in between the figures. The flowcharts are used to analyze, design and document the process [20]. There exist standardised figures representing certain actions when creating flowcharts, but since the flowchart needs to match the scope of this master thesis programming wise, use of the advanced figures becomes redundant. Instead the philosophy of flowcharts and an inspirational model of traditional flowchart methodology was used. The flowcharts were divided up relating to the different steps in the BWS-process, meaning new flowcharts were made for each step, see Appendix A3-A6.

The design process had external input in the form of theoretical knowledge from the master thesis student, the input being the red circles: knowledge, literature and experience. The reason to include these external inputs, as seen in the figure 4.5 was that the "Design Result" box needed refinement as testing the programming logic through the project required loops. An iteration was made possible as new external input was acquired, further improving the design result. This iteration process was done until the visual part and the logic part met the design principles and user needs.

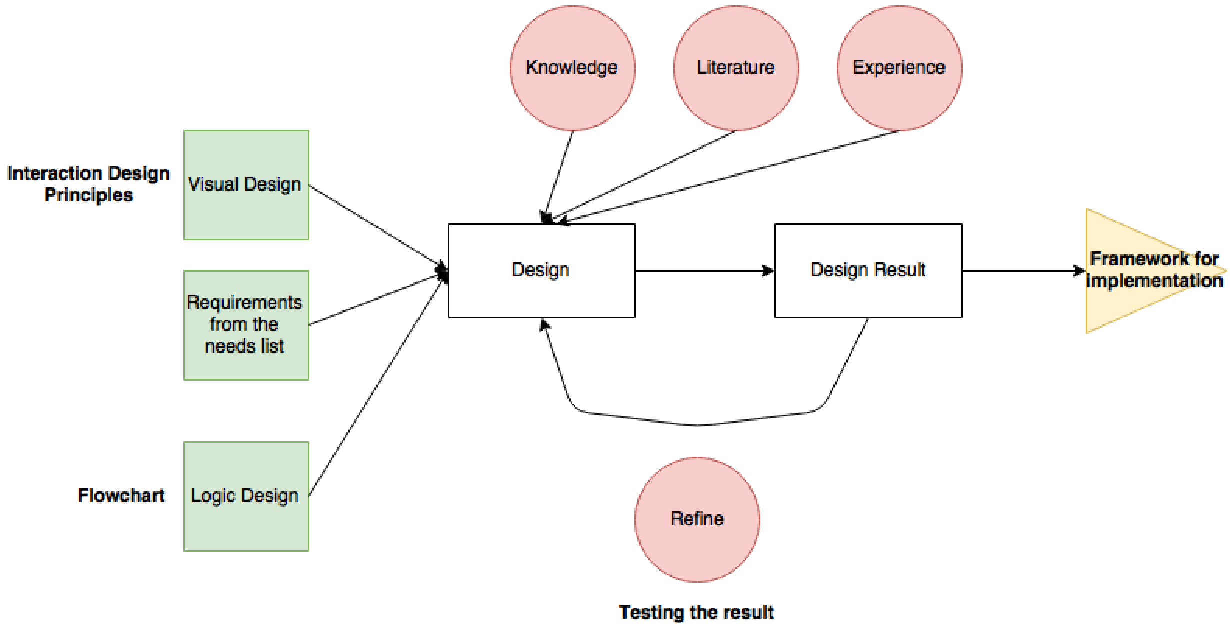


Figure 4.5: Figure showing the overview-process of the design and the iteration and refinement as experience and knowledge within the project greww.

4.3.3 Implementation of the "Balancing While Synthesizing"-Process Into Microsoft Excel

The goal with the implementation is to actually make the software according to the previous steps. The master thesis student collected knowledge on VBA-programming which is what Microsoft Excel is using when creating code. The implementation phase was heavily based on the lean start up philosophy created by Eric Ries and how it could be applied into game development (Minimum Viable Game) by Tyler York [23]. The idea of producing lean products from the start was very suitable for the project scope since it was created by one master thesis student. The important idea that Tyler presents, which was applied in this master thesis, is "Only include the necessary features. If the feature you're building isn't required for the player to run the game and complete the experiment, then you don't need it. Don't build a save game system, variable graphics settings, or even a starting menu into your Minimum Viable Game. Each of these features wastes your time, increases the number of things that can break, and doesn't contribute to your core goal. Just put the level online and let players have a go at it". This philosophy was used when implementing the software into excel for each step of the BWS-process. An example would be not making dynamic elements from the start. Meaning that users are only able to input a maximum amount of performances in the process, so that focus is on completing the products core features before adding secondary features. This also means that the implementation process was broken down into primary, secondary and tertiary mechanics. In this context a mechanic is a function within the software, for example a mechanic would be "plotting the performance profile". With the focus on making the primary mechanics realised first, an example of primary mechanics would in this case be making a performance plot and uploading images for the morphological matrix and so on. Tyler also emphasises that to save time, it is important to use excising code for tasks that are similar. Something that was used in the implementation phase, for example finding excising macros (excel programs) that solved mechanics.

4.3.4 Testing Step

The goal with the testing step was to find faults or bugs with the software or if there was anything important that was missing. The master thesis student and Lars Almefelt, the examiner, did this by testing each mechanic of the software. Feedback lead into further refinement of the software. Also the needs list was thoroughly examined so that no user need was unsatisfied and that the BWS-process did not loose any functionality.

5
Results

The following chapter contains the results of the method used in this master thesis project. Spanning from the internal research, external research, final concept, and the software development.

5.1 Result From Data Collection and Pre-Study

The data collected in the pre-study resulted in valuable information, this section presents the data in different subsections according to the subject.

5.1.1 Strengths and Weaknesses of the "Balancing While Synthesizing"-process Prior to the Method Development Project

Previous research has pointed out some weaknesses of the BWS-process, which is what this master thesis is based upon since it is a method development project. This section clarifies the strengths and weaknesses of the tool. The outcome is also to prepare the idea generation stage of the method so that the right questions would be asked yielding a better focus on the weaknesses of the tool.

5.1.1.1 The Strengths of the "Balancing While Synthesizing"-Process

The BWS-process possesses strong attributes in how the tool allows the use of vague information in early phases of concept generation and development. This is casual since information usually tends to be vague in the early stages of product development, in particular, novel products as seen in figure1.2.

Since all combinations of sub-solutions are not studied, the tool directly becomes more efficient regarding time savings.
Previous research showed that the process implied a focus on effectiveness and overall product integration (Almefelt, 2005) and reduced risk of wasting time on detailed solutions.
The BWS-process encourages team spirit and a good product result. The opinion of the team members in this case was that the method encourages creative thinking and supports overall product solution thinking and property balancing.

5.1.1.2 The Weakness of the "Balancing While Synthesizing"-Process

The process does not guarantee an ultimate optimal concept solution, this is because all possible combinations are not studied. Something which, in the case of what the tool actually is created to achieve, may not be a weakness.
Almefelt stated that the approach still needs a more intuitive and easy-to-apply formalised approach regarding the "Functions Balancing"-step.
One can speculate that there are some other weaknesses that were not discussed in the previous research. When dealing with the "Functions Balancing"-step there are many factors to keep in mind at the same time, as presented in chapter 1.1.3. To keep the performance profile and the three other factors: Performance, Geometry (manufacturing) and the Materials, can be overwhelming since the tool does not support this at the moment.
Another possible drawback could be that the flow of the process makes it less intuitive for the users. Or that the visual presentation used for the "Functions Balancing"-step, does not support the work in a good enough way for the users.

5.1.2 Result From the Internal and External Research

The information collected in the pre-study is specifically presented in the following subsections.

5.1.2.1 Identified User Needs List With Weighted Criteria

The customers needs list used in the report emerged from interviews conducted from prior research in combination with the external search. The needs list is presented in Appendix A1. The figure shows categories of needs grouped in a heretical structure, denoted by capital letters. It is noteworthy that the groups target the objectives and general needs but they do not necessarily share connection between each other. The needs were given weights according to how important they were to the users, the objectives within the project and the theory study. The blue rows were needs identified as needs focusing on the digitalizing and were not given focus while doing the sub-solution screening and scouring. Instead they were given focus when digitalizing the process, see section 5.3. The needs list was continuously updated as the development of the project advanced.

5.1.2.2 Whats Done By Others and Has There Been Any Other Successful Digitalizing of Methods?

It is noteworthy that the research study on existing digital versions of concept development methods did not find any competitive tools within the time limit of this project by the master thesis student. Instead the search was made with a more broad vision. This resulted in finding out about tools within the topic of "Creative Ideas". Appendix A2 lists the 63 different tools [29]. There was not time to investigate all of the tools, but a handful of tools was chosen by the master thesis student. One of these was the "Brainstorming Toolbox", a software package which supports brainstorming sessions [5]. The tool is described by the creations "Infinite

Innovations Ltd" as: "Brainstorming Toolbox is the latest software to make your brainstorming sessions quicker, better and more interesting. By having Brainstorming Toolbox on your computer you will have the best and most interactive creative prompts at your fingertips. Spark off your ideas at the touch of a button...". The interface was deemed as not pleasing and not desirable by the master thesis student. The software was very simplistic regarding its mechanics and eventually found not helpful as input for the master thesis.
The STRATEGO-tool was found as a successful digitalization of a method, in this case a manufacturing strategy process, the tool was made within Microsoft Excel. The STRATEGO-tool was examined and aided input towards supporting the decision of picking Microsoft Excel, it also yielded inspiration towards the visual design. The "overview"-section, is a visual element of the digitalized BWS-process, which is presented in section 5.3.3.2 and is inspired by the Excel version of the STRATEGO-tool. Figure 5.1 shows the STRATEGO-tool and on the left side of the figure a similar element is seen as the "overview"-section of the BWS-process.

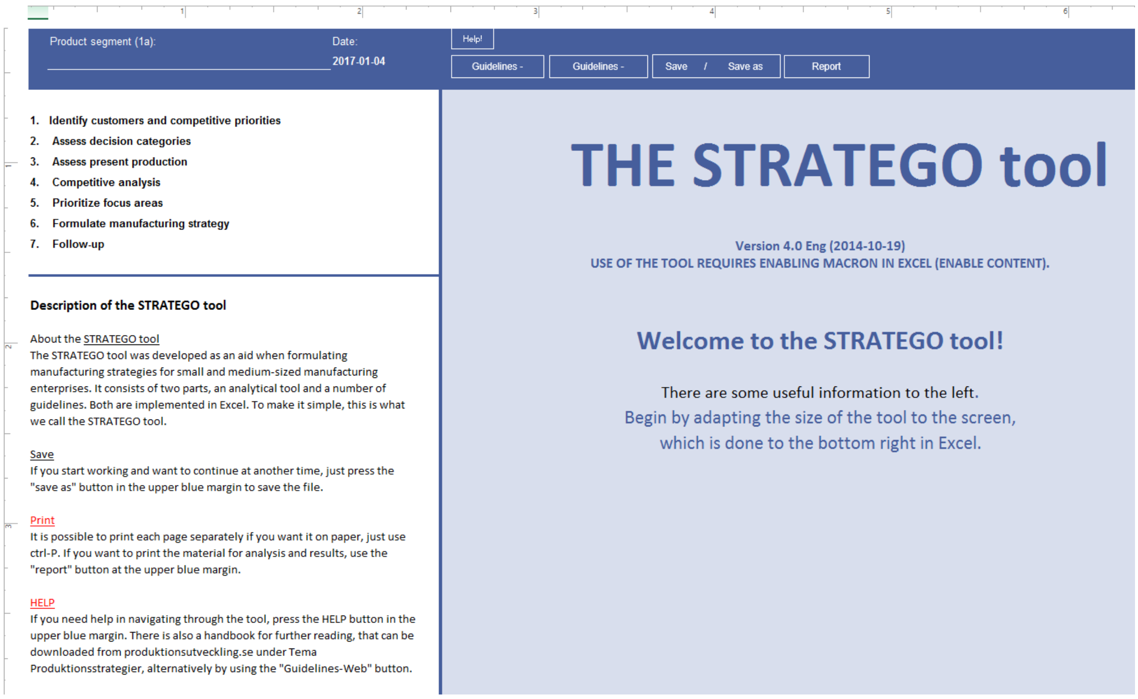


Figure 5.1: An overview image of the STRATEGO-tool [35].

5.2 Method Development Results For the "Balancing While Synthesizing"-Process

This section presents the result regarding the whole process of the method development for the "Functions Balancing"-step. This is one of the objectives of the master thesis project. The information gathered from the research methods supported all parts of the sub-solution generation.

5.2.1 The Groundwork for the Sub-Solution Generation Regarding the "Functions Balancing"-Step Improvements

As mentioned in the methods section, the project started out with understanding how the BWS-process works. One of the results is the function analysis of the BWS-process illustrated in figure 5.2. The analysis shows the input parameters being the assignment, requirements, and ideas from the users. These input parameters go through the blue box which is the process itself containing different functions within, and out comes the output, which is a concept.

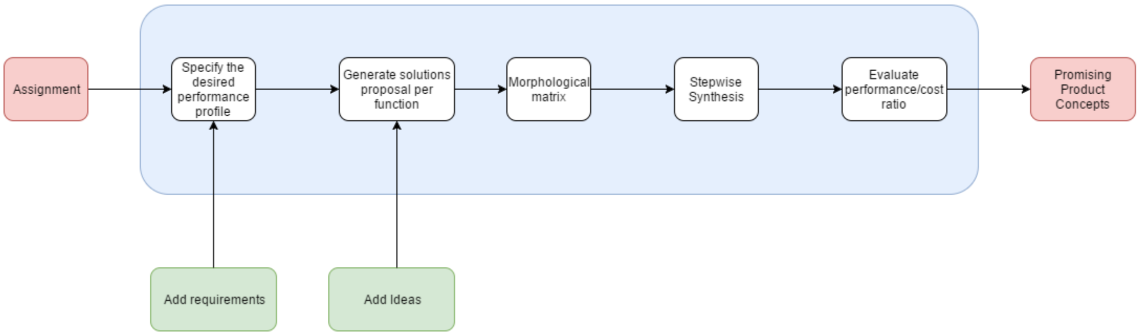


Figure 5.2: The "Balancing While Synthesizing"-process as a functions structure.

5.2.2 An Overview of the Generated Sub-Solutions for the "Functions Balancing"-Step

As mentioned in the methods chapter, in section 4.2.3, the idea generation sessions were based on answering different questions. The outcome was a broad set of sub-solutions regarding the issue. New questions made the master thesis student think of creative ideas since the questions restricted and angled the thought process in different ways. Figure 5.3 shows the different categories of sub-solutions generated as a result when the generation phase was completed. This result was made by analysing and compiling each sub-solution and putting solutions that acted within the same category together which in the end resulted in the four different classifications. Keep in mind that the "Functions Balancing"-step is a function within a process, just as figure 5.2 shows. This means that the solutions are just made to solve the "Functions Balancing"-step. Also, keep in mind that the morphological matrix and all previous steps in the process are assumed to have been performed by the users while suggesting possible new ways of performing the "Functions Balancing"-step (this may not be true if the process is changed in some way).

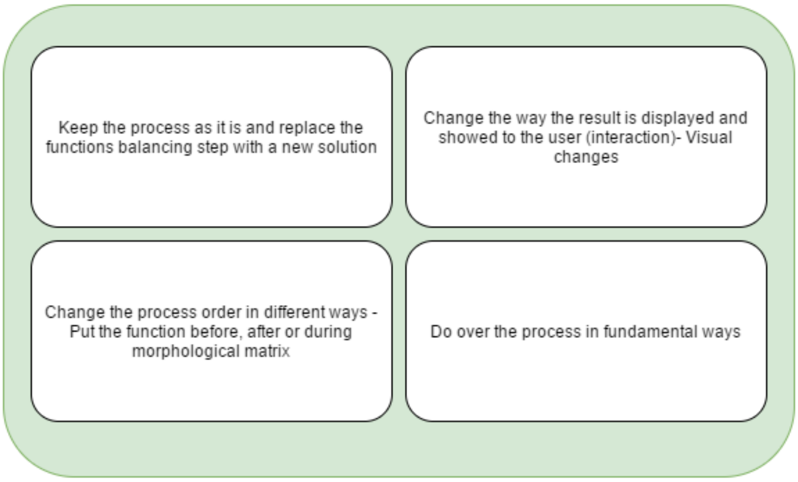


Figure 5.3: The four categories made up by the classification of the sub-solution results.

5.2.3 The Process of the Idea Generation Itself

This section presents the different ideas for sub-solution for the "Functions Balancing"-step where generated from the brainstorming sessions. The ideas were first sketched on a piece of paper. The sketches helped visualize how the process actually worked with the use of so many sub-solutions.

5.2.4 The Sub-Solutions From the Idea Generations Sessions

In total 12 sub-solutions with different characteristics were generated, all with the goal to solve the objective of the master thesis. Each sub-solution was remade from scratch to a concept image. In this case a concept image is a representation of how the sub-solution solves the "Functions Balancing"-step. The following part will present each sub-solution with a short description. It is noteworthy that the solutions below target a diverse set of answers of how to solve the question.

Sub-solution 1: Stepwise With Cost/Performance Balance. The main idea with this solution, displayed in figure 5.4, is to combine the "Evaluation"-step (the last step of the BWS-process) with the "Functions Balancing"-step. The combination will achieve a shorter and faster process. This is done by assessing the performance and cost instantly while comparing sub-solutions with each other. The assessment itself is easy since it only requires a grade from one to five. This results in a focus on the cost and performance ratio much earlier in the process.

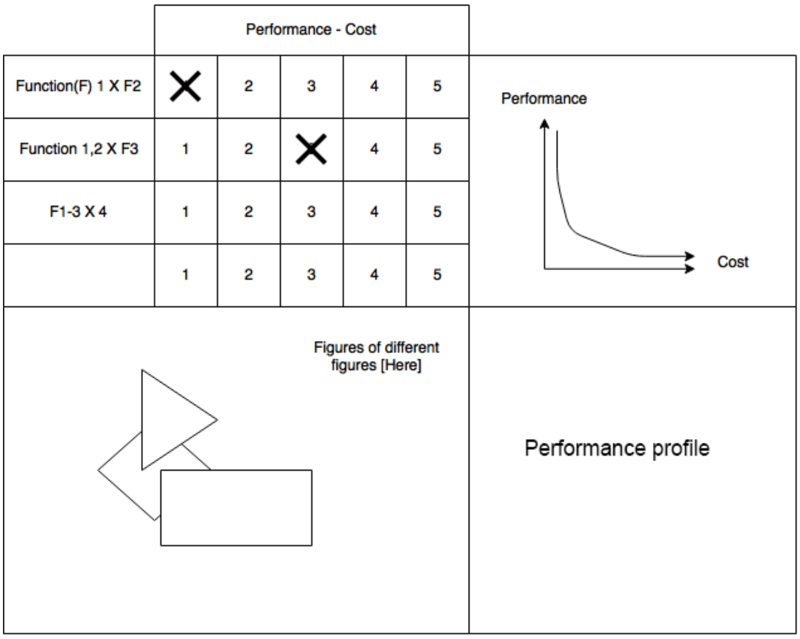


Figure 5.4: The "Stepwise With Cost/Performance Balance" sub-solution.

Sub-solution 2: Simple With Grading. The basic idea with this solution is to reduce the variables while doing the balancing assessment between sub-solutions. Instead of focusing on different parameters users only answer one overall question, "What is the Synergy?". The parameters of the original synergy assessment are presented (Conflict, Low Synergy, Medium Synergy, High Synergy) as seen in figure 5.5 and these are in focus instead of design and performance profile. This means that the assessment is reduced from (if a performance profile is made up by eight performances) 12 factors to four factors. This reduces the complexity by a significant number and eases the iteration process and overall speed of the BWS-process.

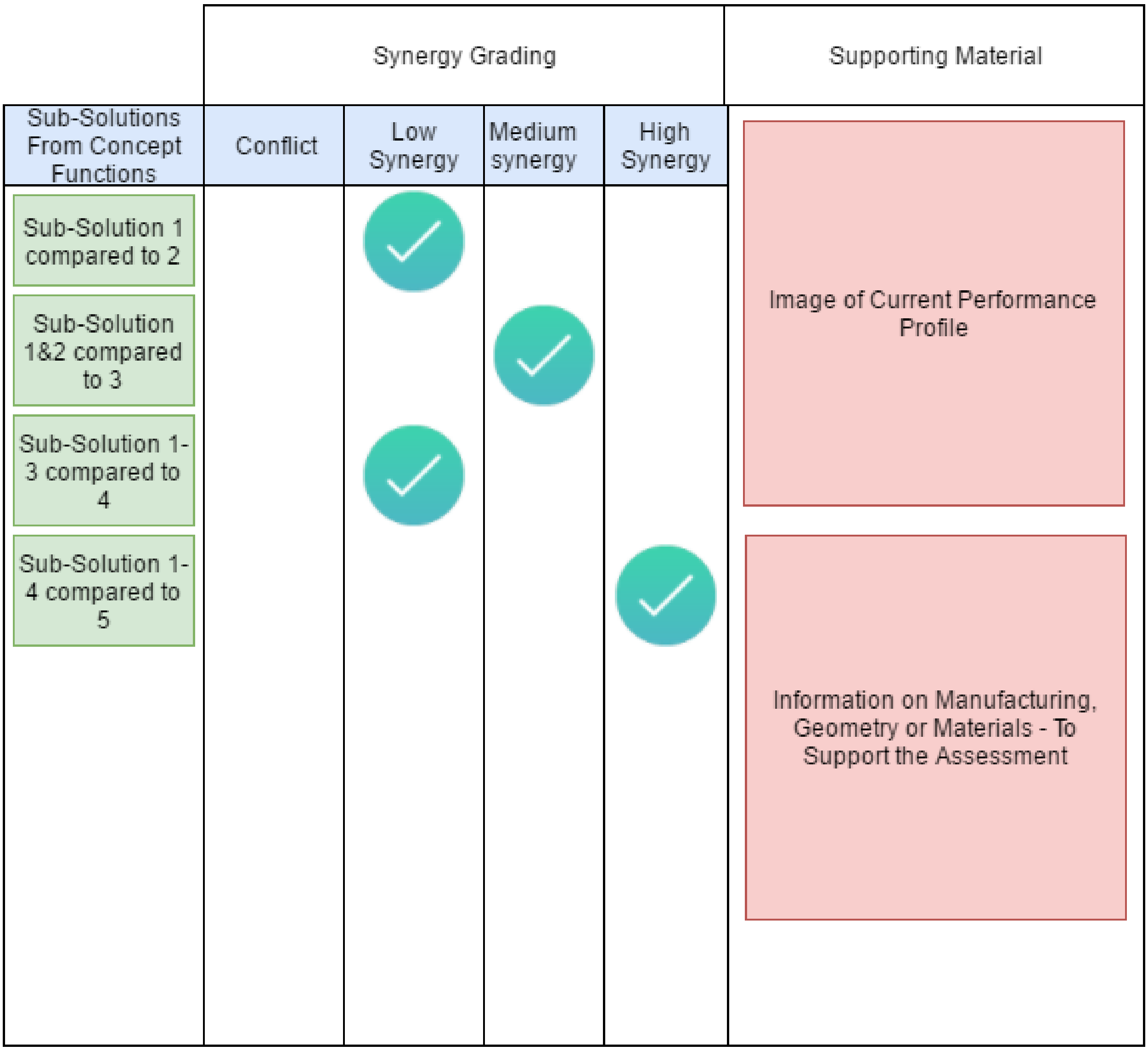


Figure 5.5: The "Simple With Grading" sub-solution.

Sub-solution 3: All Design Parameters With Grading. This solution is like number two, but instead applied to all design parameters and performance profile, the materials assessment, and performance profile are exemplified in figure 5.6. This resulting in a grading process somewhat like the previous version but with a more intuitive process since users are constrained to answer one parameter at a time resulting in consistency.

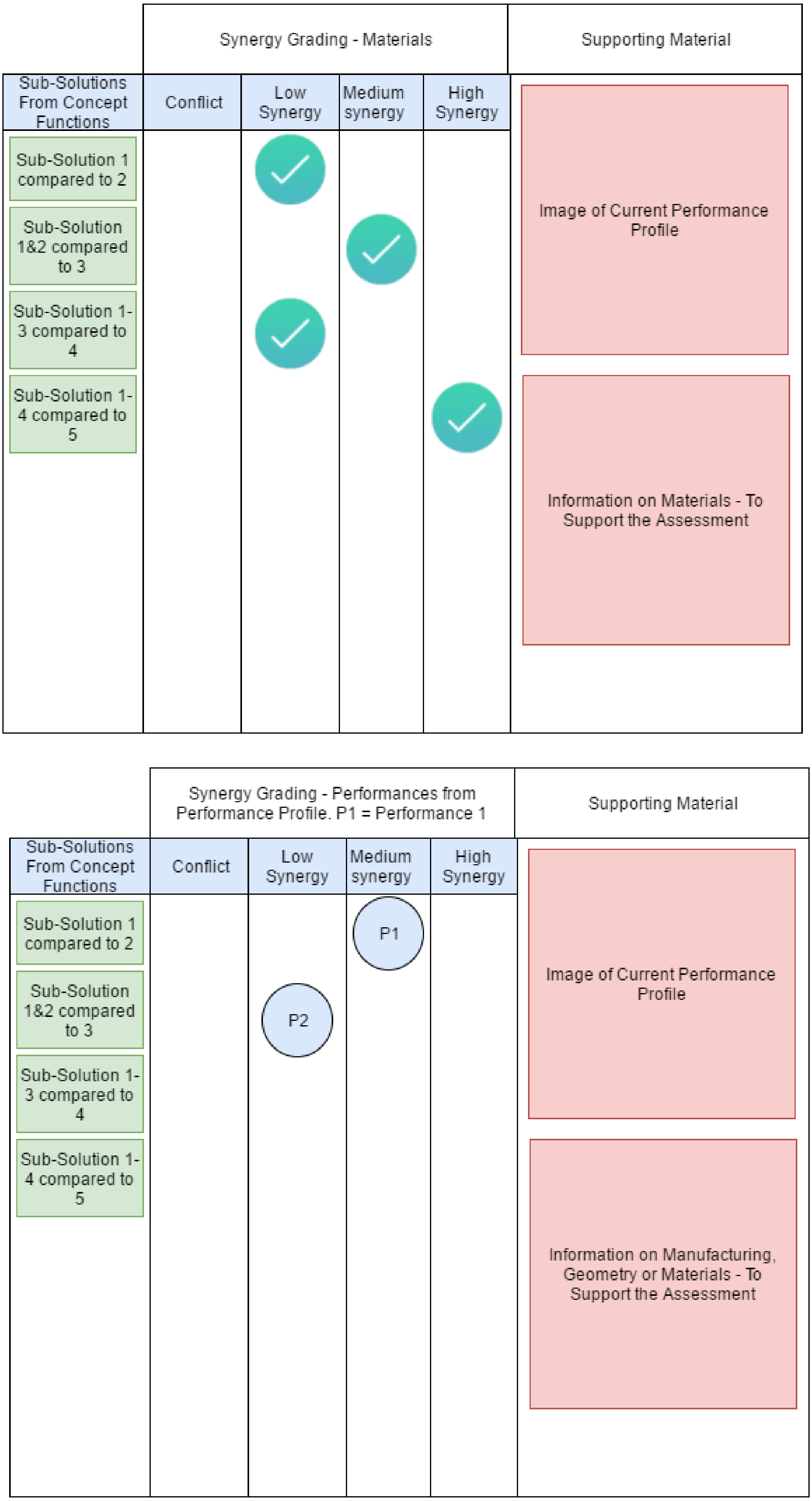


Figure 5.6: The "All Design Parameters With Grading" sub-solution.

Sub-solution 4: Flow-Step Images. Focuses on constraining users action but still giving an overview of the process. This solution is focuses heavily on the visual elements of the process. Users are presented with an overview of the synergy assessment using a timeline which shows the current step, as seen in figure 5.7.

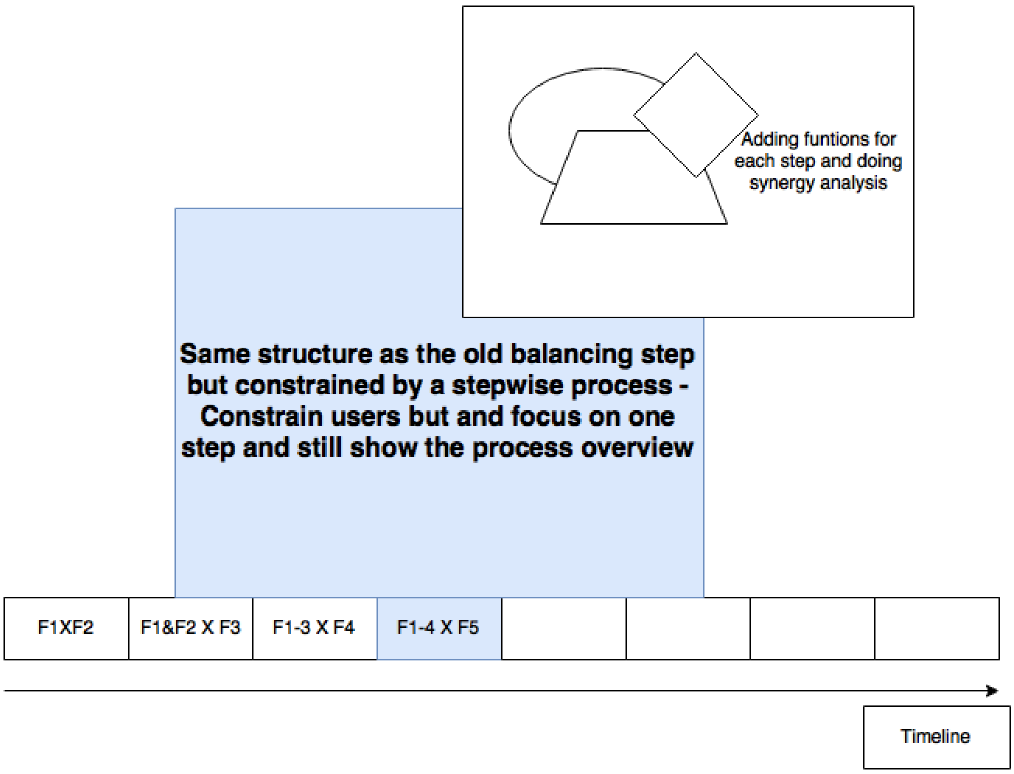


Figure 5.7: The "Flow-step images" sub-solution.

Sub-solution 5: 3-Axis. A solution heavily focusing on simplifying the visuals and thereby activating a more intuitive assessment of the different factors. Figure 5.8 shows an example of such a solution when users assess a heavily simplified solution. This could potentially be realized by other visual solutions such as the images from figure 5.9. The performance profile is not assessed in this model.

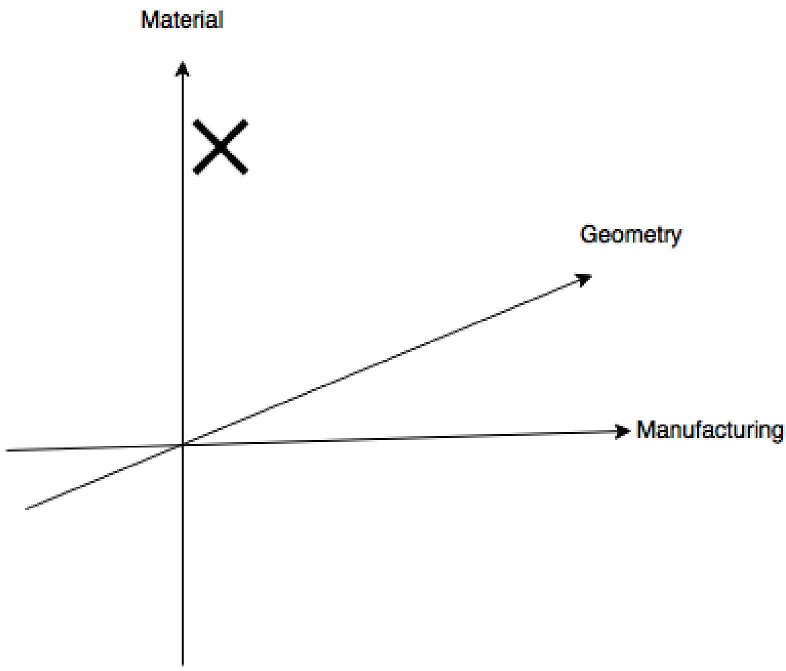


Figure 5.8: The "3-Axis" sub-solution.

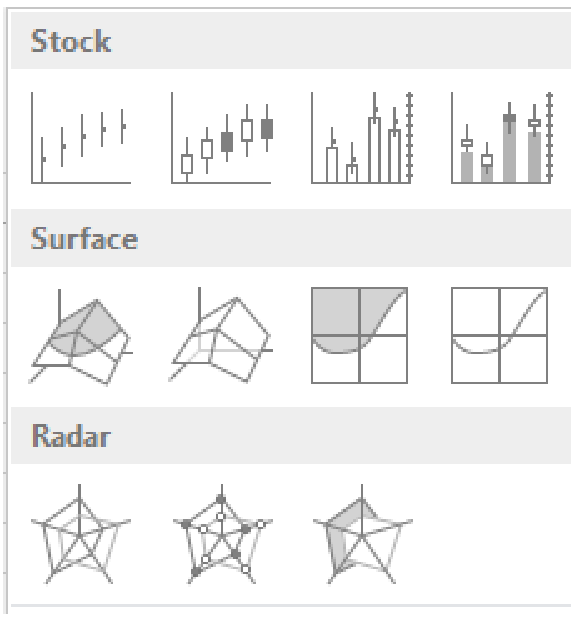


Figure 5.9: Other ways of displaying the solution. The image is from Microsoft Excel.

Sub-solution 6: Aligned Process. This solution is unique in the sense that it requires the users to do the synergy analysis directly as sub-solutions are combined to form a concept. This means that the synergy analysis and the morphological matrix are combined into one step. Figure 5.10 shows two sub-solutions being compared and assessed instantly as they are combined to form a future concept. The result is that the mentioned steps are, as the name suggests, aligned with each other.

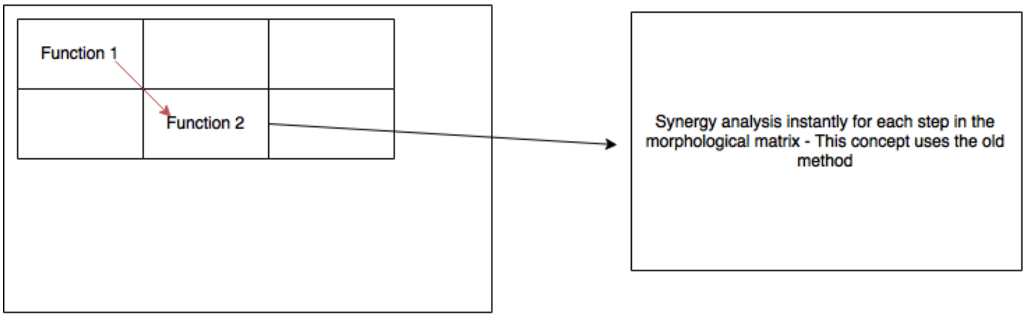


Figure 5.10: The "Aligned process" sub-solution.

Sub-solution 7: Separated Design Parameters. The core idea with this solution is to focus on the design parameters as seen in figure 5.13 which shows a suggestion of how to separate the parameters using a triangle. The performance profile is taken into account in this solution and assessed as previously in the method development project.

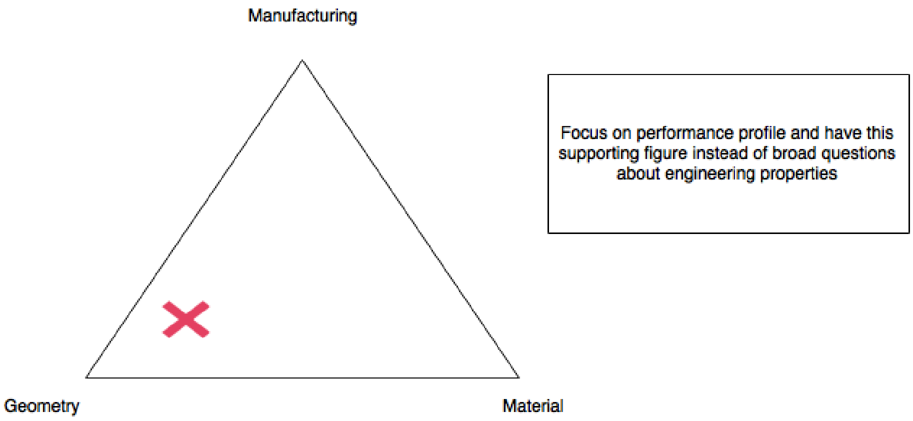


Figure 5.11: The "Separated Design Parameter" sub-solution.

Sub-solution 8: DSM-Synergy. The solution in this case is influenced by the DSM technique [31]. The solution makes an extensive analysis of the different interactions between the sub-solutions marked "F" in figure 5.12. Solutions are graded by the same four grades and denoted by a character in the matrix as seen in figure 5.12. It is worth noting that this solution would require extensive information about the concept and all the decision parameters, if users would construct such a matrix.

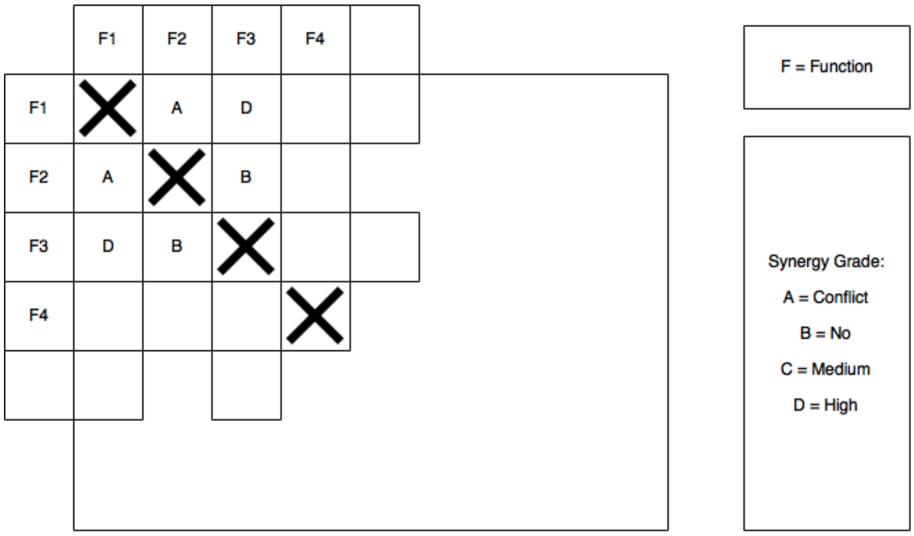


Figure 5.12: The "DSM synergy" sub-solution. Note that the character "B" which says "No" is short for low synergy.

Sub-solution 9: The CK-synergy. This solution is based on the CK-theory [24] and works in the same way. The left side is the concept space and the right side is the "Knowledge"-space. The users first start with a sub-solution, in this case, "F1" as seen in figure 5.12. The sub-solution "F1" synergy is assessed between all sub-solutions in the next row of the morphological matrix, this is the "balloon" bellow "F1". Then solutions are brought into the knowledge space, hence the arrow called "F2" in figure 5.12. The Knowledge space gives grounded information about the different parameters which makes the synergy possible and furthermore makes it possible to expand the most interesting sub-solution which fits with sub-solution "F1". The same process is repeated for the number of sub-solution rows in the morphological matrix.

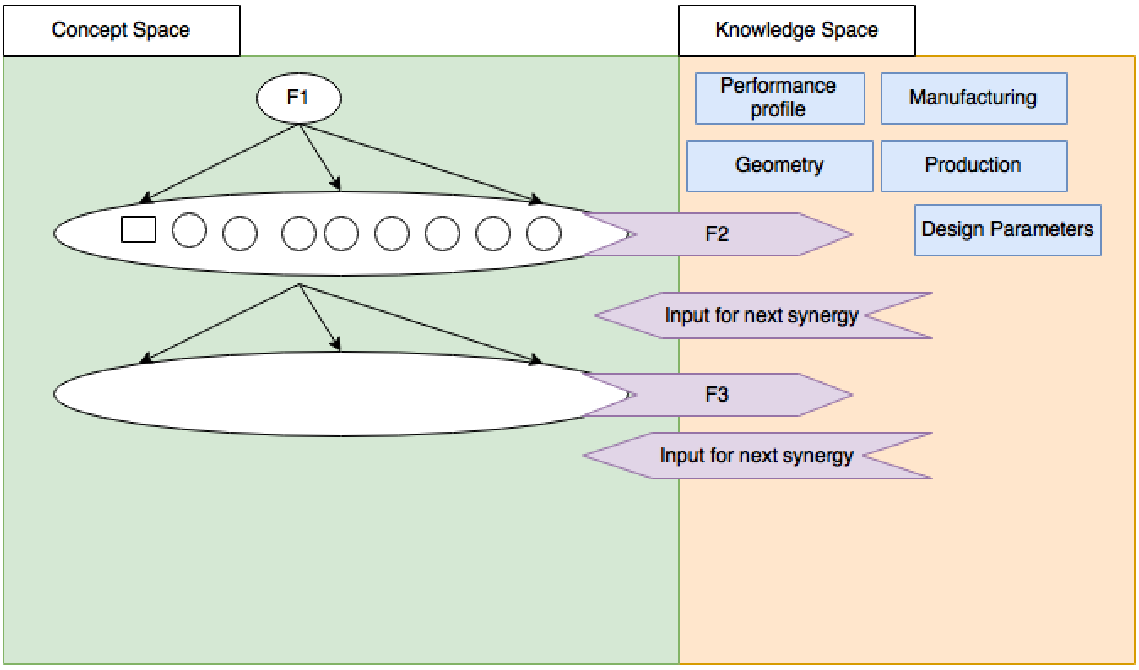


Figure 5.13: The "CK-synergy" sub-solution.

Sub-solution 10: Cascade Synergy. The Cascade Synergy solution is inspired by a control-design-loop. The cascade-loop is made up of two loops, a quick controller which will adjust quickly and an outer loop that adjusts depending on the result. The benefit is having a part that can quickly adjust the process before it reaches consequences for the whole process [6]. The way it would be realized as a solution is by the concept figure 5.14. Composed of a primary loop, the green area on figure 5.14, being an activity where users make a smaller lighter synergy assessment which would require little time and effort. After this the next loop compares the sum of current functions in more depth and if the primary loop did not manage to cover the synergy a new assessment is made in the secondary loop to compensate for this. Then the process is repeated starting from the primary loop with a new function.

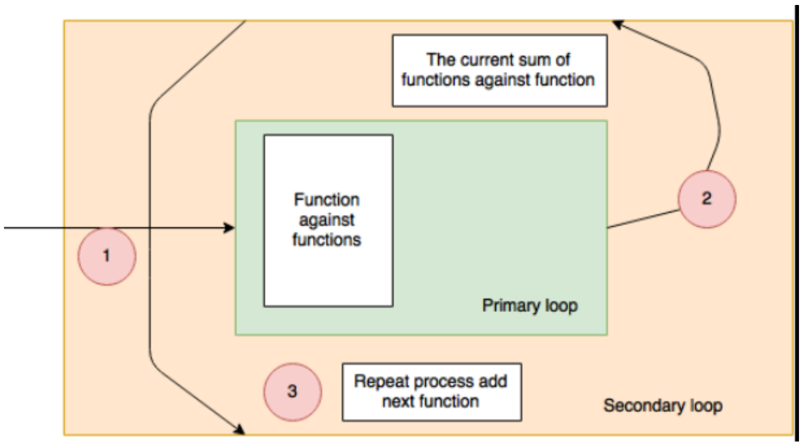


Figure 5.14: The "Cascade Synergy" sub-solution.

Sub-solution 11: Three Option Method. This solution is influenced by the drafting method for cards in the game "Hearthstone" [26] as seen in figure 5.15. The "drafting" part of the game is when users, or in this case players, need to pick between three possible candidates in each turn to assemble a "deck" of cards. The application grades the cards, illustrated by the circles under the cards in figure 5.15, showing a number that corresponds to the synergy the card has with the current set of already chosen cards and the overall value the card possesses by itself. The best pick is graded with a crown above the score itself and different colors are given to the score corresponding to how good it is. A text above the cards communicates and justifies the grade and gives the users a suggestion for what to pick. The previously picked cards are views to the far right. Keep in mind that this solution requires a digitalizing to be working as suggested bellow.

Figure 5.15: The "drafting" suggestions showing a rank and a suggestion text on the top, for the three options available [26].

Figure 5.16 shows the adaptation using the Heartharena-application for the synergy assessment in the "Functions Balancing"-step. Figure 5.16 shows the first step in the process, users get a suggestion of possible sub-solutions within the first row of the morphological matrix. In figure 5.17 users have chosen a number of sub-solutions and the software suggests three different sub-solutions from row four in the morphological matrix with a percentage of synergy presented below each sub-solution. A synergy grade is given by evaluating and balancing between the prior picked sub-solutions. The hypothetical solution would in this case also take into account the design parameters and the performance profile.

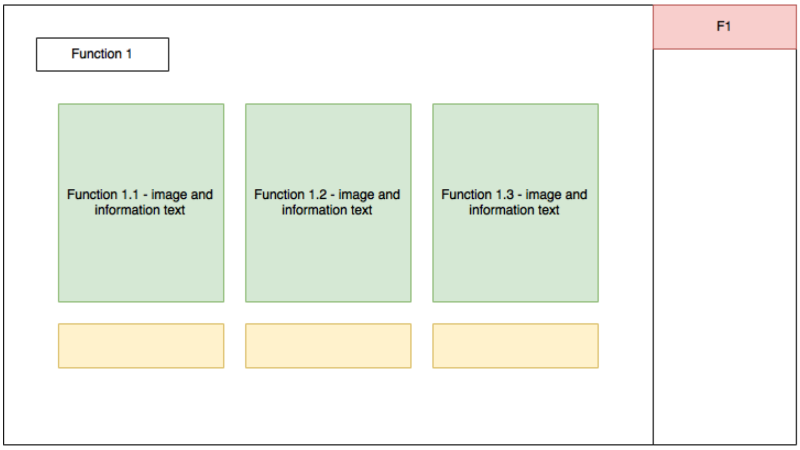


Figure 5.16: The "Three Option Method" sub-solution when at the first picking stage.

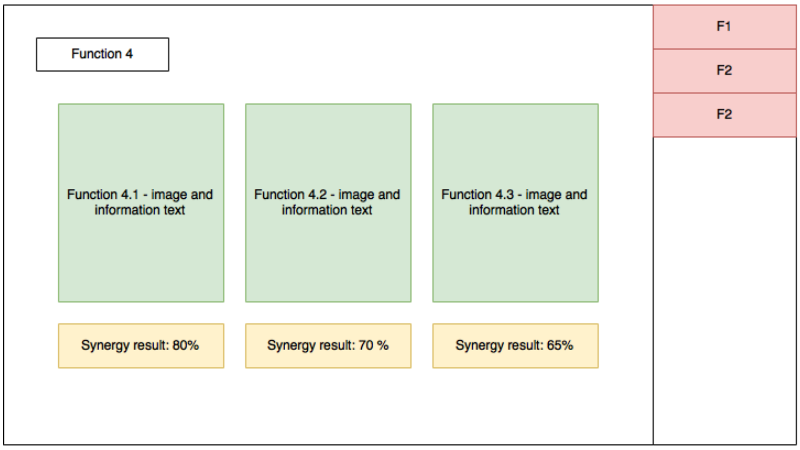


Figure 5.17: The "Three Option Method" sub-solution when at the fourth picking stage.

Sub-solution 12: Super AI (Artificial Intelligence). This solution is carried out by using an advance algorithm which suggests the most optimal synergy analysis suggestion amongst all available sub-solutions. Users would be guided through the process with minimal effort and different suggestions would be presented by the AI.

5.2.5 The Result of the Sub-Solution Scouring and Selection

The generated sub-solutions were put into the weighted needs list to be scored against each other, as seen in Appendix A1. The old process of the "Functions Balancing"-step was also evaluated against the new suggestions. All the solutions in the needs list were then scored on how well they fulfilled the particular need.

5.2.6 The Scoring Result Including the Combinations

After the scoring process (grading each sub-solution), three candidates (marked yellow in the figure/table in Appendix A1) with the highest scores were chosen as candidates for cross combination. The combination was done using the highest scoring sub-solutions (sub-solution 2, 4 and 6) and pairing them together making up three new solutions. The combination of number 2 and 6 is the "Aligned With Grading", the combination of number 2 and 4 is "Simple grading with Flow-step images" and the last combination being "Flow-Step Images with Aligned Process" is a cross over from number 4 and 6. Hence all sub-solutions were put together at least once. The combinations are marked as green in the Appendix figure A1, as they also received scores from the weighted needs list. The winner, the sub-solution with the highest score after the cross combinations was a combination of sub-solution 2 and 6 the "Aligned With Grading" sub-solution.

5.2.7 Result and Winner From the Concept Selection - The New "Functions Balancing"-Step

This section presents the result of the scoring process, the "Aligned With Grading" which received 10 points more than next highest scored sub-solution. The scores of each sub-solution are presented in Appendix A1. In respect to the BWS-process, users make the balancing between functions instantly when adding together functions from the morphological matrix. It is noteworthy that this makes the process clearer, increases consistency as well as providing a constraint towards what users should do at each step. One of the core research questions was to make the process more intuitive which is visible through the refined balancing activity. The new way is composed through a less data-dense procedure compared to the old one. The core principle here is to; 1) condense the user's alternatives and variables into a much lower complexity number resulting in a faster process, 2) not loose the quality of the balances between product properties, 3) store the balances of product properties so when iterating the process, data and information are not lost.
The synergy analysis itself is constructed by giving a grade while comparing sub-solutions with each other from the morphological matrix. This new synergy analysis is made up of the four grades. Users can now score the correct synergy grade when comparing the sub-solution with each other, note the low amount of complex decision-making (four grades). The users can read about the performance profile and engineering properties if more input is needed as a supporting activity, they are not required to grade these. An example of the new synergy assessment would be: User first picks sub-solutions from the first and second of the morphological matrix, then instantly assesses their synergy by using the new grading system. The next step would be that users select a sub-solution from the third row of the morphological matrix- The selected sub-solution is then compared to the sum of the sub-solution selected before and a new synergy assessment is made by giving a new grade. The second iteration is now done and this process is iterated until one sub-solution from each row in the morphological matrix is added, resulting in a finished system concept proposal.

A new aspect and function is added to the new "Functions Balancing"-step, which is that by the end of the balancing step a value is presented to the users. This is a grade on how good the overall synergy was after a synergy assessment hence a synergy grade. Moreover each balancing grade maps a score from zero to three (conflict=0, Low Synergy=1, Medium synergy=2 and High Synergy=3). If a sub-solution of the final concept would get a “conflict” score, the synergy grade would instantly result in a “0 percent-synergy grade”. The highest possible score is divided by the current score of the concept and a final synergy grade is presented as an indication of how well the synergy is between the sub-solutions. This result is an output that is not wasted between steps of the BWS-process but is rather a concrete argument towards deciding a final concept through iterations within the BWS-process.

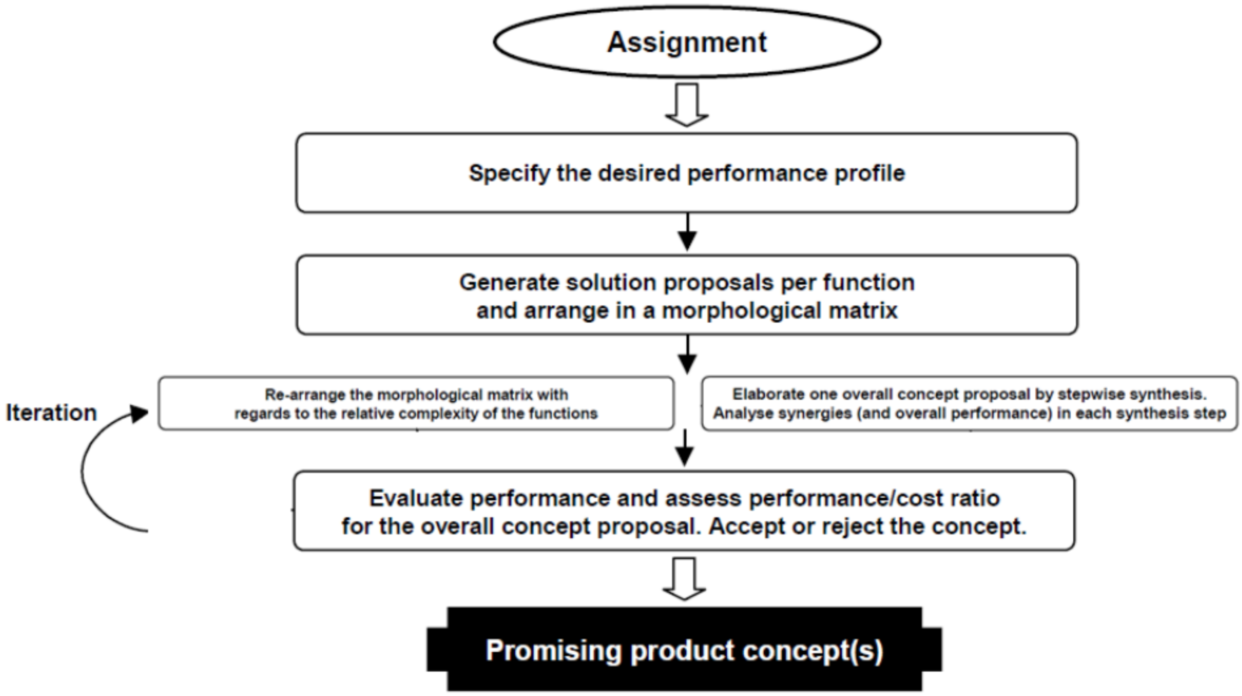


Figure 5.18: A fundamental view of the solution and an overview of the new BWS-process inspired by Almefelt [1].

5.3 The Result of Digitalizing the "Balancing While Synthesizing"-Process

The digitalizing result is split up into the same four steps identical to the "Applied Waterfall"-model’s four steps, which was the method used in this project when digitalizing the BWS-process. The sections below will present the result from each step in the process in a chronological order after presenting the result from choosing the software package. Keep in mind that the digitalizing is not completed, the core functionality of the "Balancing While Synthesizing"-process was in focus to keep a feasible scope.

5.3.1 Choosing the Software Package

Choosing the right software package was done by grading each candidate, see figure 5.19. The grading matrix was made up by decision factors aimed to pinpoint future and present issues and factors. Both the developer of the software and the user of the software were in focus, hence the "Classification of Needs". The candidates were found by searching for how to develop software as well as past knowledge that the master thesis student required. All the decisions which had the "Classification of Needs" called "Developer", as seen in figure 5.19 were based upon the master thesis student. It was clear that the suggestion "Microsoft Excel", was a clear winner. This suggestion had no "red-grades" and the highest number of "green-grades" compared to the other suggestions.

Classification of Need	Developer	Developer	Developer	User	User	Developer(s)	Developer	User
Decision factors:	Software Language (Working in the software)	Learning the Software	Realise All the Critical Parts of the BWS-process	License	User accessibility (installment and usage)	Enables Future Development	Cost to Acquire Software	Possible End-Aesthetics of Software (Visual)
MATLAB	Green	Green	Yellow	Yellow	Red	Yellow	Yellow	Red
Microsoft Excel	Green	Yellow	Green	Green	Green	Green	Green	Green
C++ Language	Red	Red	Green	Green	Yellow	Green	Green	Yellow
C Language	Red	Red	Green	Green	Yellow	Green	Green	Yellow
Java	Red	Red	Green	Green	Yellow	Green	Green	Yellow
Web-based Software package (online package)	Yellow	Green	Red	Yellow	Green	Green	Green	Green

Figure 5.19: Grading matrix with classifications, decision factors and the suggested software packages. Red is "unachievable" green is "acceptable" and yellow is "caution/need more information".

5.3.2 Result From Requirements Step of the "Applied Waterfall"-Model

The requirements step was as mentioned presented as the needs list presented in section 5.1.2.1. The blue lines in the figure of Appendix A1 were additional needs while incorporating the whole needs list as requirements for the digitalizing. The needs ranked "3" were highly focused while continuing the process and the needs list was visited several times to ensure that the quality and the needs were met at a standard which would satisfy the objective with the report and not risk the quality of the tool. It is of importance to state that the implementation of the process proceeded in such a way that the users can go back and forth in the process without interrupting the process. This means that if a change needs to be made in one place, it does disturb the continuation of the process.

5.3.3 Result from the Design Step of the "Applied Waterfall"-Model

The result from the design step is divided into two steps, first is the logic design of the process and then the result from the visual design.

5.3.3.1 Result of the Logic Design

This subsection presents the logic which was a foundation for the digitalizing. As mentioned in the method section, simplified flowcharts were used as tools for logic design. First, a general logic schematic was made, see figure 5.20. This flowchart shows the interactions and the input and output in the process and the different process steps and their classification (the text above the blue blocks). The flowchart is heavily simplified and does not take into account the interaction itself.

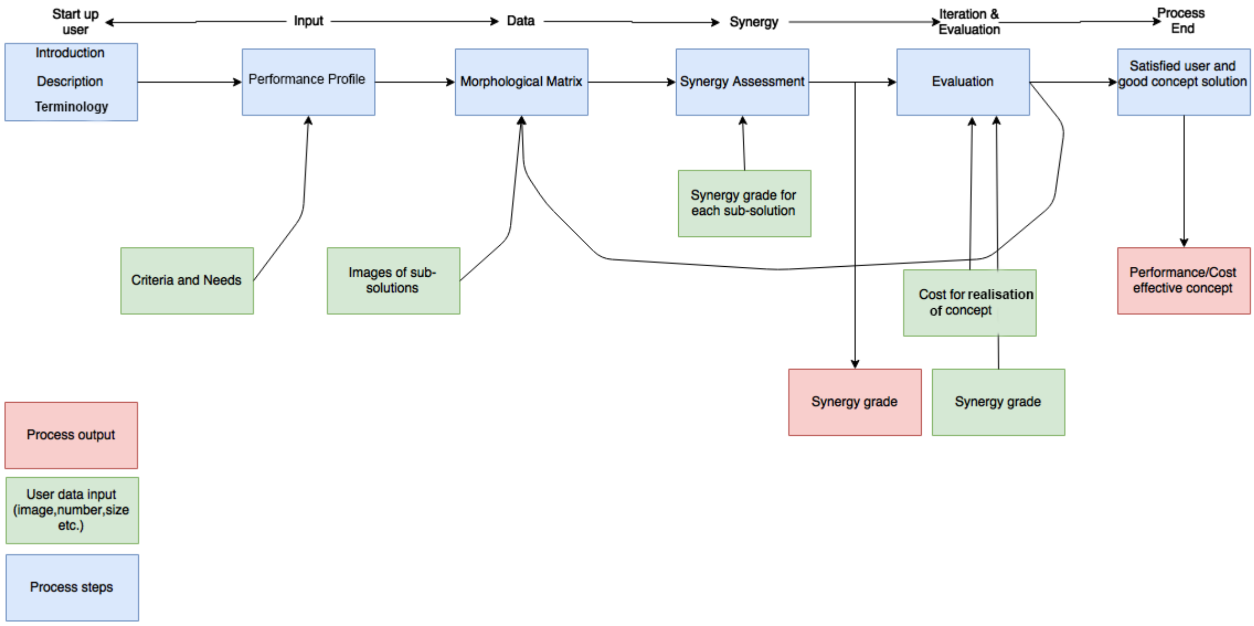


Figure 5.20: A fundamental view of the solution and an overview of the new BWS-process inspired by Almefelt [1]

In Appendix figure A3-A6 the following flowcharts for the process steps are presented. The blue block called "Process Steps" was made into a flowchart with the exception of the "Start up user"-block which did not require any logic.

5.3.3.2 Result of the Visual Design

The visual part of the software is based upon interaction design and visual design. The tool is divided up into two visual sections. These are illustrated in figure 5.21, the green section is the "overview section", and the orange section is the "actions section". Keep in mind that the focus of the figure is to show the visual design and the layout, more about the implementation itself regarding the different steps in the process is presented in the subsection below. The "overview section" in figure 5.21 contains a rigid set of elements which is constrained and does not change while using the BWS-process. Moreover the overview-section is divided into four elements, starting from the top: The name of the process, the information section, the process section and the process description section. The importance is shown in a hierarchy where the users can see the most important actions on the top. It is noteworthy that the process steps are coloured and larger making these pop out for the users to easily guide their eyes towards following the steps of the process. The "action section" is basically giving users input and output of each step in the BWS-process, requiring a larger portion of the available screen space i.e. the bigger orange space in the figure 5.21.

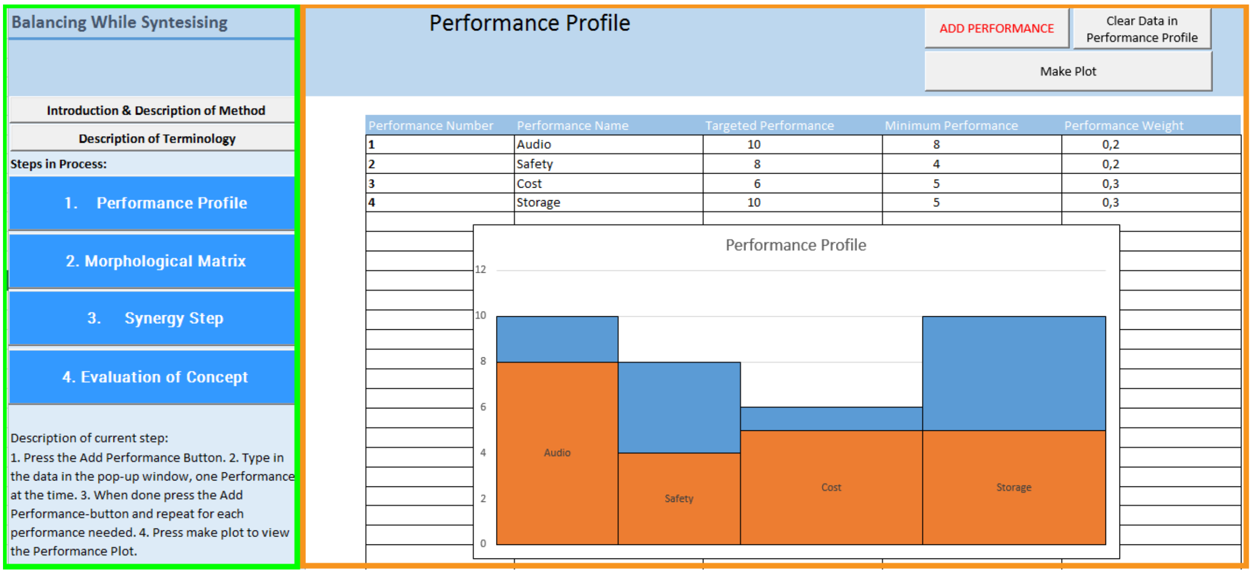


Figure 5.21: Showing the "overview section" (green) and the "action section" (orange) layouts of the digital "Balancing While Synthesizing"-process

5.3.4 Result of the Implementation Step

This section presents the result of the implementation and creation of the digital version of the BWS-process. This is done by dividing up the process into five different steps according to the flowchart of image 5.20 i.e. all steps except the last one which is not a specific software process step. This is done in a chronological order showing all of the results of the digitalizing and its implementation. The following sections will only show figures of the "overview"-section within the software since this sections content changes between each step.

5.3.4.1 Start Up User - Introduction, Description and Terminology

This step consists of two pages in the software, represented by two gray buttons on the "overview section" in a chronological order as seen in figure 5.22. First the users need to be informed of the process (introduction) and then how to use the software (description) and then if needed, information on terminology, this is the reason behind why they are set up in the presented order. The two buttons, as seen in figure 5.22 are smaller in size and are gray. It is noteworthy that this is done because these "start up user" activities are not in the "main process" marked in blue in the figure 5.22 but rather made up since it was found important from the user needs list. These buttons correspond with text and information regarding the current topic.

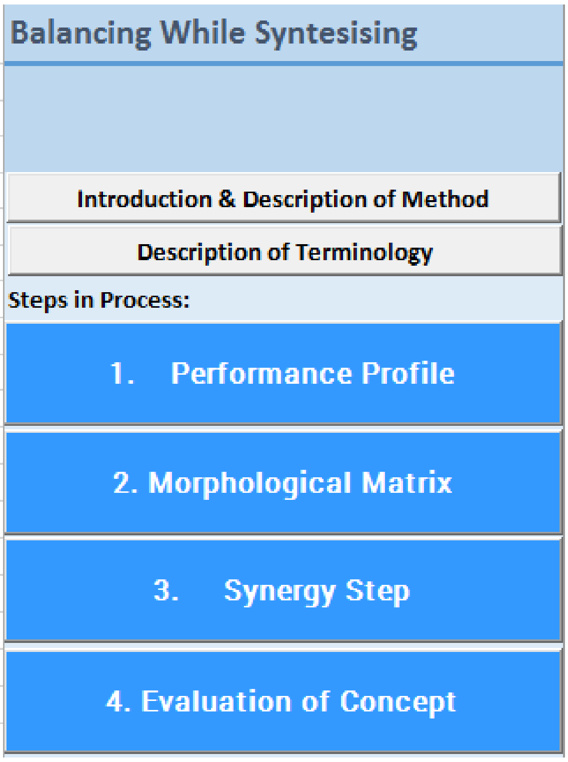


Figure 5.22: Showing the “overview section” with the focus on the "Start up user" section with its included parts as the two gray buttons

The "Introduction Description of Method"-button contains a section describing the process steps and a section which describes the general information about the process. The process section contains an informative text about how to navigate through the process, and the "general information about process"-section contains information about the goal and advantages of the process. The "Description of Terminology"-button contains the meaning of phrases and words used in the software, to get the users up to speed fast.

5.3.4.2 Performance Profile as a Digital Version

The performance profile is the first step when the users wish to begin the process. What the users will see first is the table visible in figure 5.23. Here users need to input their desired parameters of each performance in their project, as seen in figure 5.24. This is done by pressing the button "ADD PERFORMANCE" in red, note the placement (highest up) and the color (red not black as the other buttons on screen) which directs the users attention to the button. When pressed, the users are presented with a window requiring the users to input the data. An information strip helps the users to write in the correct data in the correct space as seen in figure 5.24. If a user does not input any data and leaves an input parameter empty the software prompts a window directing the users to add the missing information. This process is done for one performance at a time and the users can see the matrix build up in front of them. They can at any time alter or delete the data in any column or row if desired. When the process of adding performances is completed, the users press the "Make Plot"-button to create the performance profile as seen in figure 5.23.

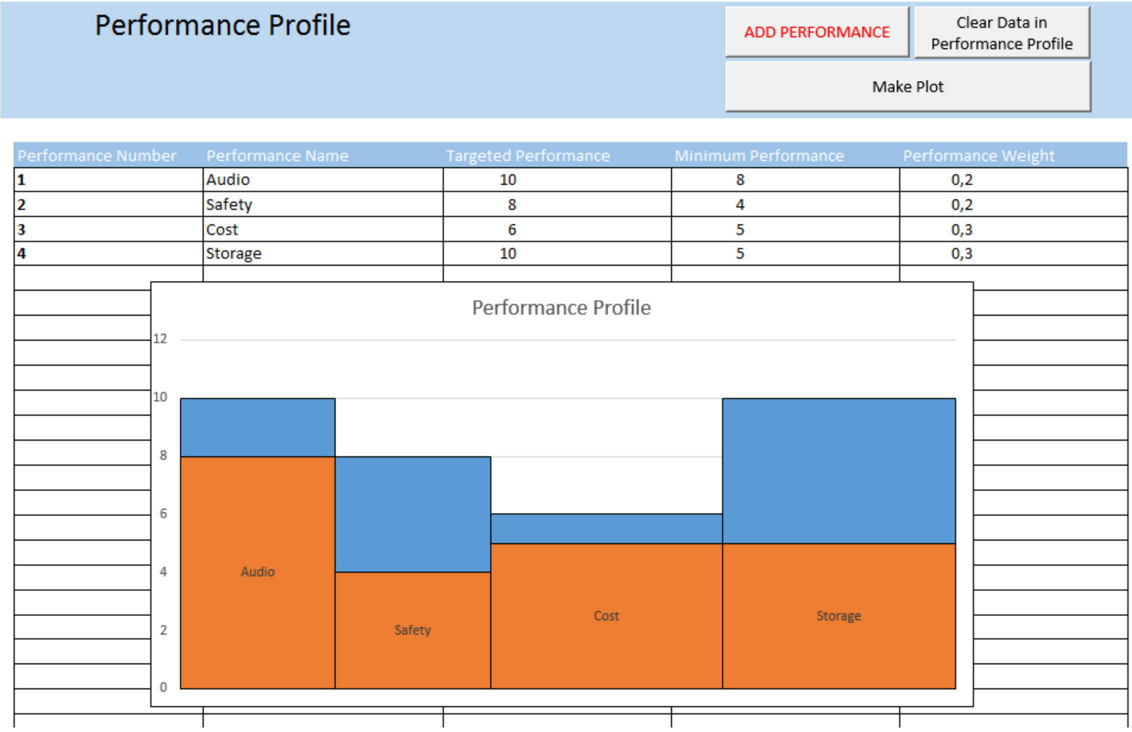


Figure 5.23: The first step of the enhanced "Balancing While Synthesizing"-process, the creation of a performance profile.

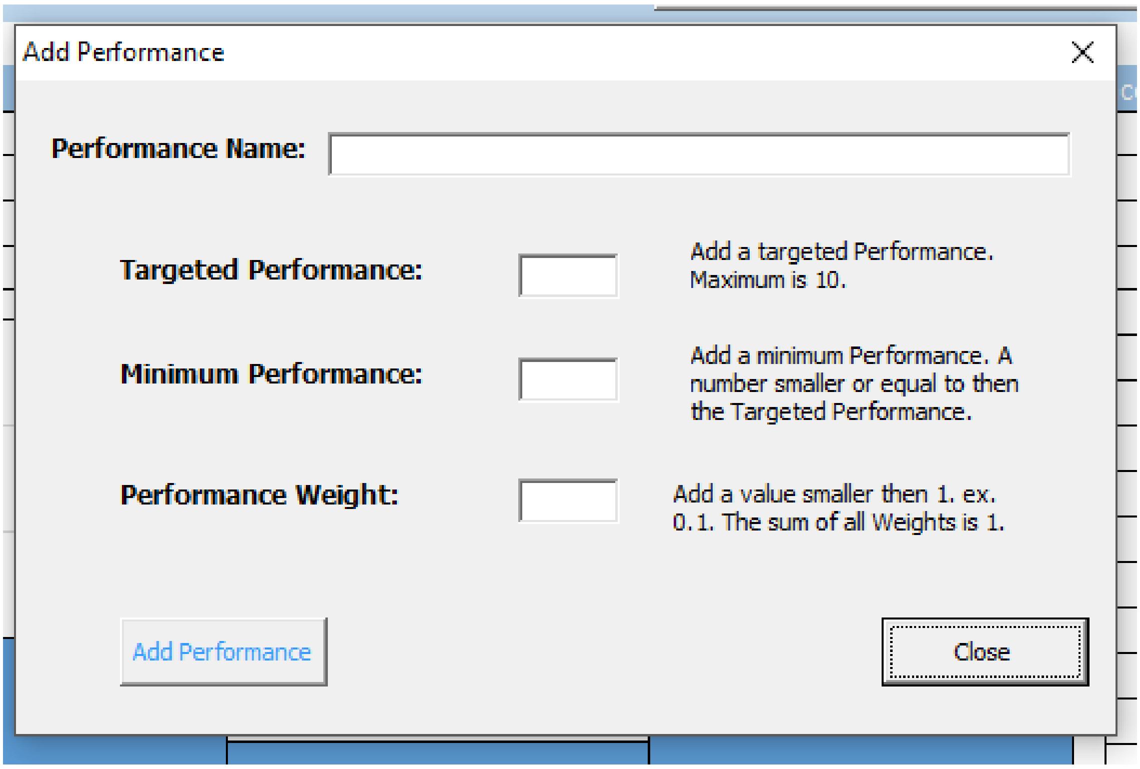
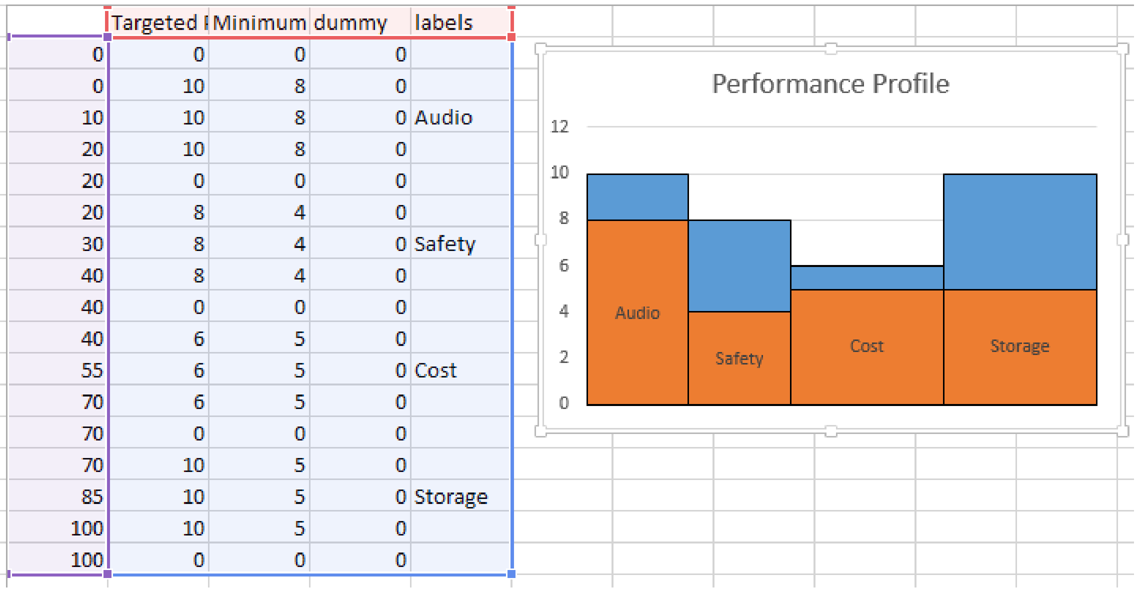


Figure 5.24: The window which users see when the "ADD PERFORMANCE"-button is pressed.

The plot does not appear in the same window/page in which the figure is altered.

The reason for this is that the technique which produces the plot with the specific aesthetics of the performance profile is not built in as a standard plot in Microsoft Excel. Instead the technique of "Variable Width Column Charts (Cascade Charts)" is used [28]. This requires the plot-data to be placed in the upper left corner of an Excel sheet, as seen in figure 5.25. The users need to locate the sheet and use the copy/paste function to relocate the performance profile plot to the main screen. The titles of each individual bar are created using the "The XY Chart Labeler" which simplifies the process of adding names to the bars of the plot [3].



	Targeted	Minimum	dummy	labels
0	0	0	0	
0	10	8	0	
10	10	8	0	Audio
20	10	8	0	
20	0	0	0	
20	8	4	0	
30	8	4	0	Safety
40	8	4	0	
40	0	0	0	
40	6	5	0	
55	6	5	0	Cost
70	6	5	0	
70	0	0	0	
70	10	5	0	
85	10	5	0	Storage
100	10	5	0	
100	0	0	0	

Figure 5.25: The process of making the performance profile-plot.

5.3.4.3 The Digital Version of the Morphological Matrix

By pressing the button "2.Morphological Matrix" in the "Overview"-section, the software changes page to the morphological matrix creation. This step requires users to follow the instructions, displayed in figure 5.26. When the procedure is done users press the button at the end called "Make Morphological Matrix" to generate a morphological matrix. This will only take a few seconds depending on the resolution of the images, yet again in another sheet. The reason behind this is that figures take up cell spaces in Excel, and the size alters the dimensions of the cells making the whole interface unusable. The users get directed to the sheet automatically, where the sub-solutions are now generated in their specific rows and columns as seen in figure 5.27. Note that the process becomes very simple the second time users conduct this step in the process.

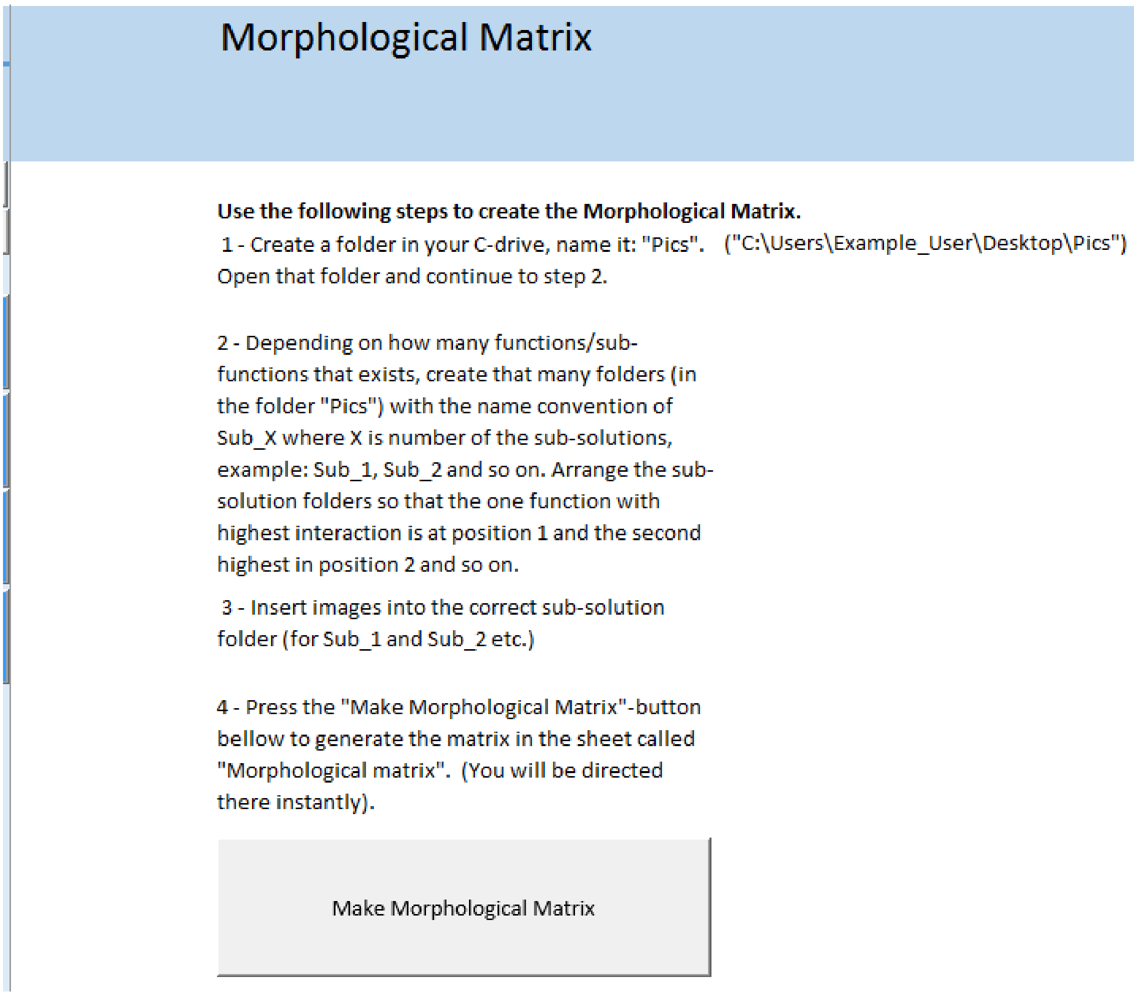


Figure 5.26: The simple procedure of construing the morphological matrix.

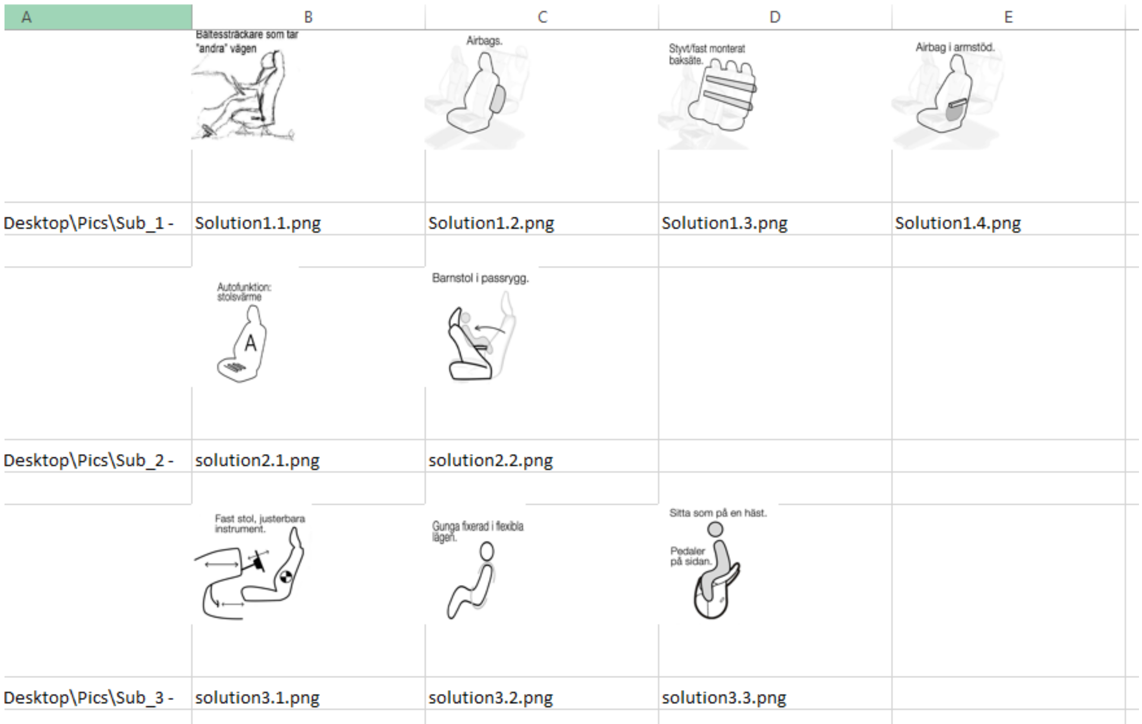


Figure 5.27: The morphological matrix constructed as the users press the button.

5.3.4.4 Synergy Step - A Digital Balancing Assessment

Until now, the software has followed the old version of the BWS-process. This step is what was called the "Functions Balancing"-step and is digitalized with the functionality just as presented in section 5.2.7. The users are presented with two sections within the synergy step, solutions viewing section and a synergy grading section. This is seen in figure 5.28, the solutions viewing section is the left column which contains images of solutions. The synergy grading section is the right part of figure 5.28 which is the part where users grade the synergy between sub-solutions from the solutions viewing section. The first step is to press the "Determine Number of Functions"-button which will populate the areas below with the number of functions and the required synergy steps the users need to perform. The user now needs to pick a sub-solution from the morphological matrix, as presented in section 5.2.7, to populate the solutions viewing section. When one row is filled, users press the red "Balancing Grade"-button to grade the current synergy assessment. When the button is pressed a pop-up window is presented containing the grade options, see figure 5.29. The window explains the grades and what the user needs to think of while doing the assessment. The performance profile is also shown for further support towards the assessment of synergies between sub-solutions.

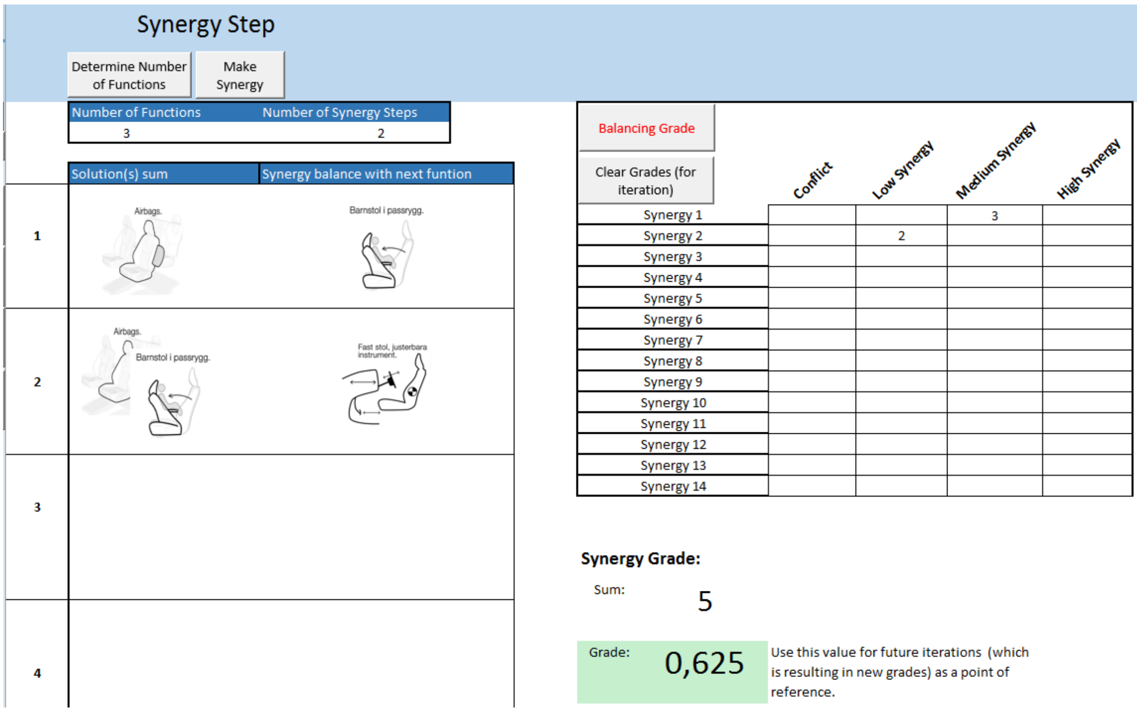


Figure 5.28: Overview image of the "Functions Balancing"-step within the digital version of the enhanced process.

Figure 5.29: The window which directs the users to grade the sub-soltuions.

When users press the assessment they press the blue button which indicates that the assessment is done. This imports the grade into the balancing grade section, as seen in figure 5.30. The grades are given from one to four and in the bottom of figure 5.30 the synergy grade is generated. This grade is the division of the sum of the total score and the highest possible score, and useful for iteration step as users get a concrete value for future reference. It is noteworthy that the synergy grade does not imply any value if not compared to an iteration with another concept solution.

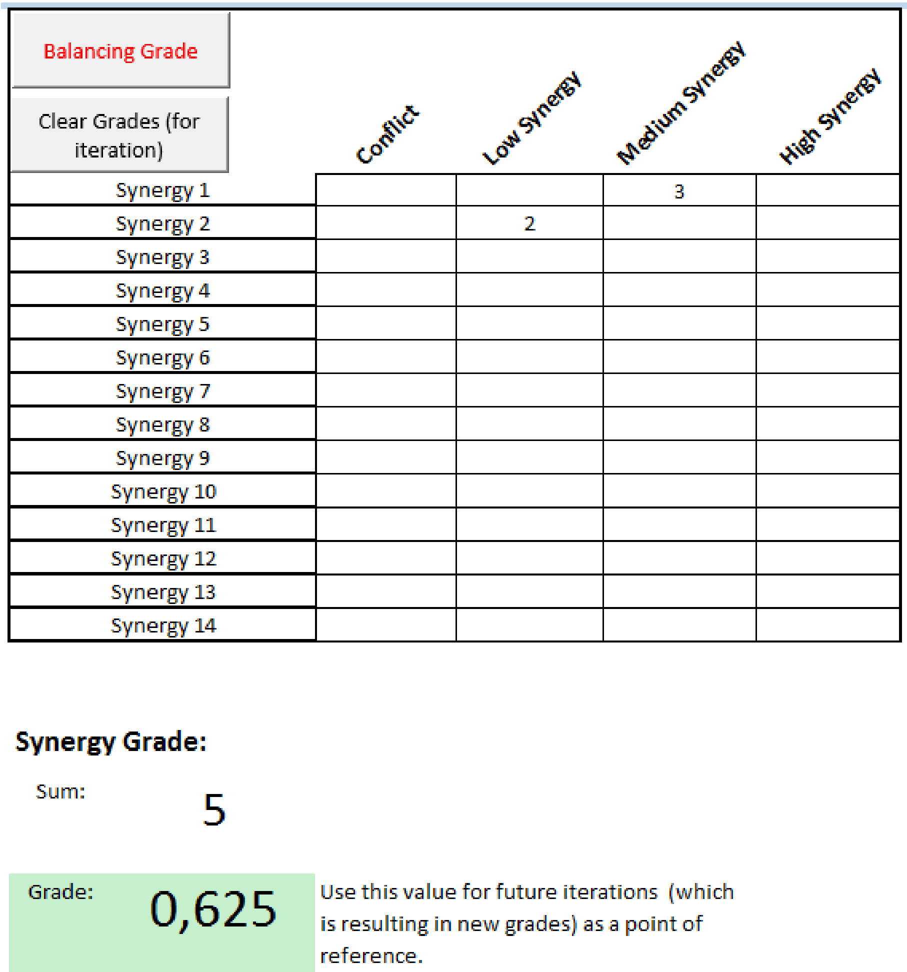


Figure 5.30: The outcome of the grading process.

5.3.4.5 Result of the Digital Evaluation of Concept

The last step in the process, the evaluation of the concept, is also within itself a five step process. As seen in figure 5.31 the users are presented with the five steps of the process to the far left marked by a darker blue color. Moving on, in the middle of the screen, users are presented with material they need to make a better evaluation. The concept images have an allocated screen space marked by a green color to make it clear where the images will go. Moreover, to the right and bottom of the screen users see numbers and values which will be the result of the evaluation. First, the user needs to import the performance profile and concepts images, this is step one and two in the evaluation process, displayed in figure 5.31.

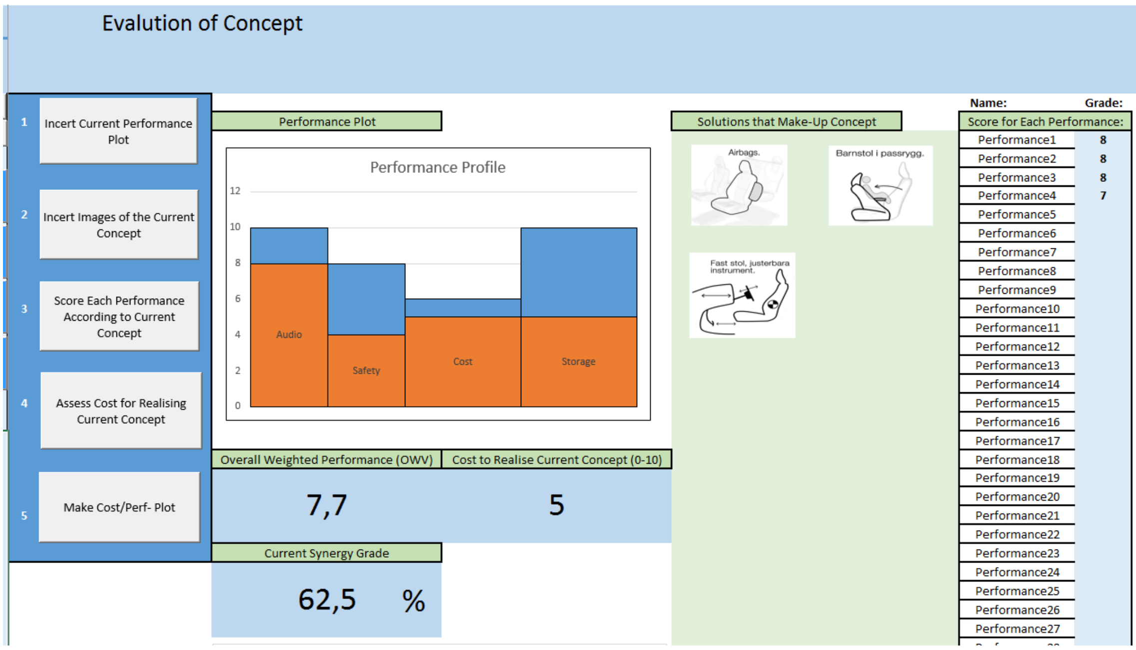


Figure 5.31: The overview image of the "Evaluation"-step. Including the five steps at the left side of the figure.

The next step is to grade the performances according to the current concept. The users press the button, button three, and the pop-up window appears. Figure 5.33 shows the window which contains the grades going from 0-10, just like the original BWS-process prior to the method development project. Each grade has a short description which makes the grading process easier, the grade will appear in the far right called the "score for each performance"-column which is visible in figure 5.31.

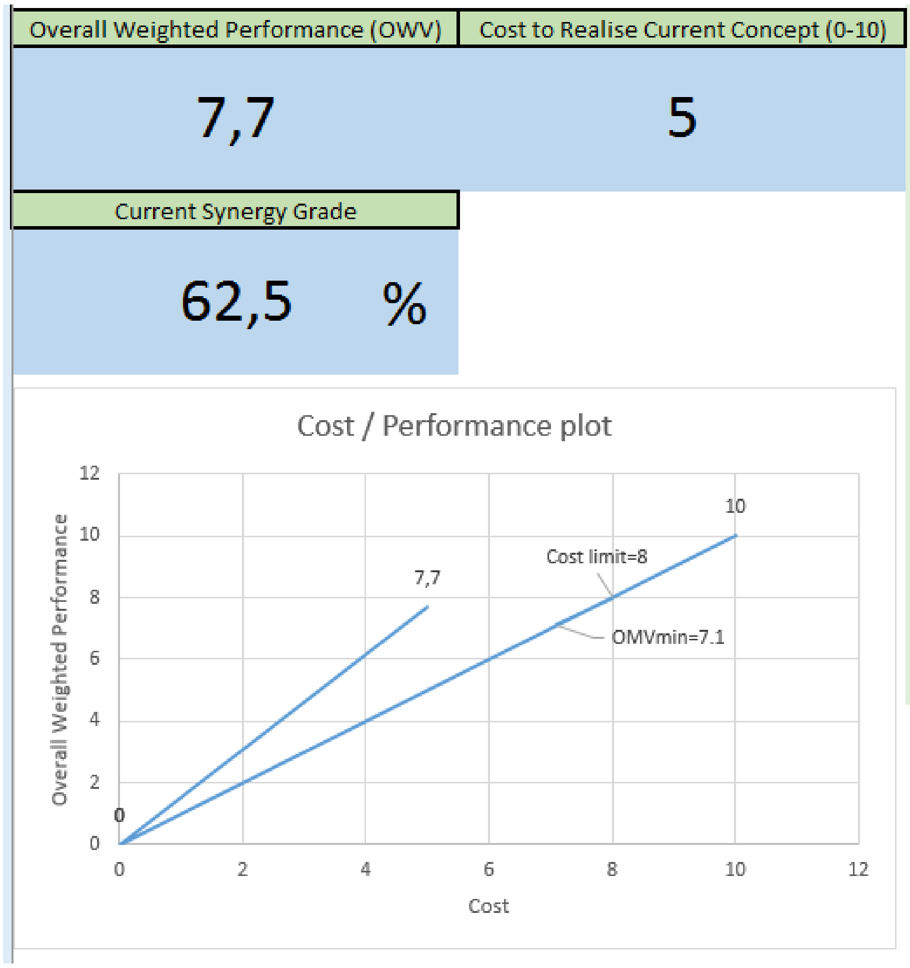


Figure 5.32: A focus on the values which support the "Evaluation"-step.

The overall weighted performance (OWV) is calculated automatically and is visual for the users at all times, see figure 5.32. Users assess the cost for the figure by pressing button four, and picking best fitting grade, see figure 5.34. Users are given information which could stimulate the cost assessment as seen in figure 5.34. The reason being that it was deemed helpful according to the needs list. The data in figure 5.32 is generated and the performance plot is created based on the data. Users can now clearly see the end result and the synergy grade. If the results from the assessment made are based on the current concept, users can start over by going back to step three in the main process, creating a new concept and starting a new iteration. As mentioned the synergy grade will provide a concrete value which the users can compare with another concept solution. It is noteworthy that there did not exist any "rest products" such as a synergy grade between iterations prior to the method development.

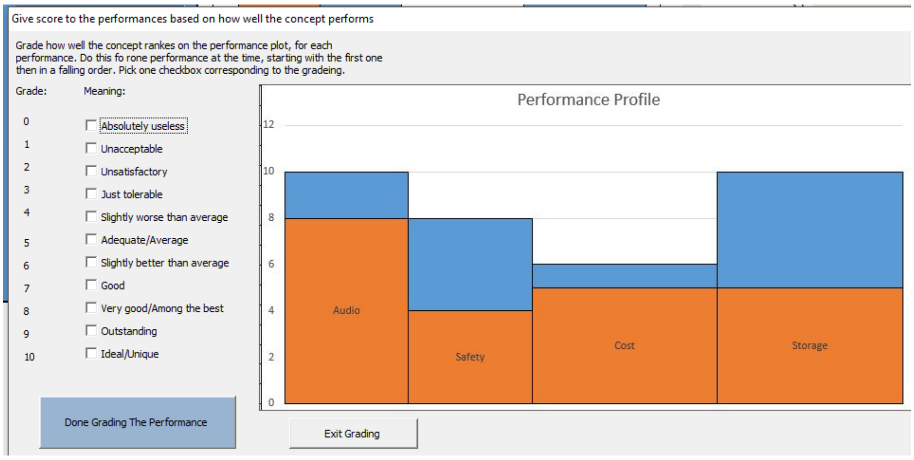


Figure 5.33: The performance grading window.

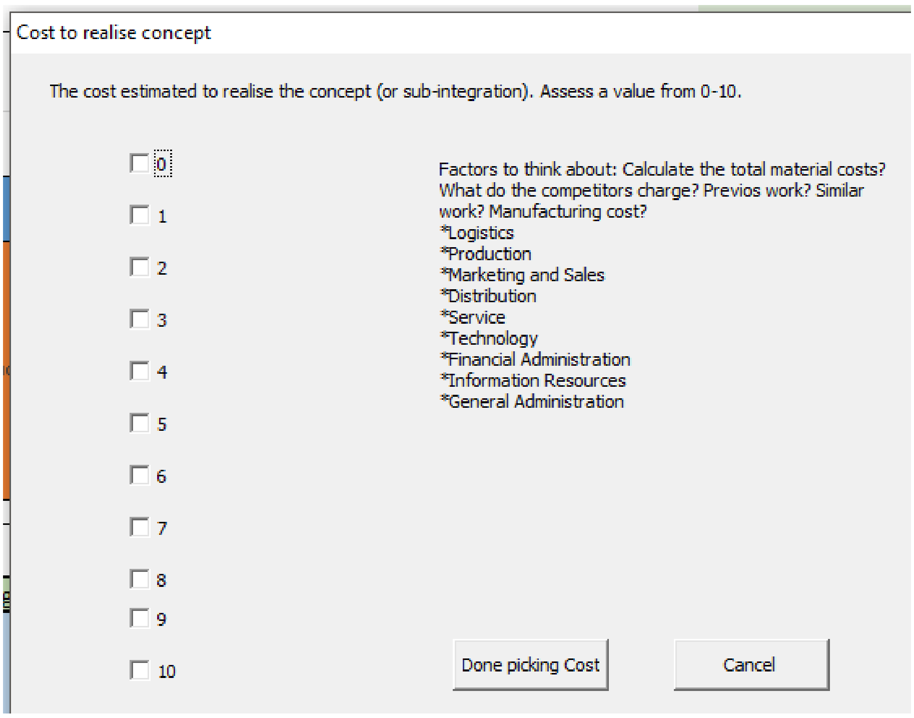


Figure 5.34: The cost assessment window with the supporting text.

5.3.5 Result of the Testing Step

As the main functionality of the process was in focus the testing phase did not require much attention. The testing was done continuously by the master thesis student with the reference of the non-digital version and the flowcharts. The examiner of the master thesis was shown the process and gave feedback as a way of testing the software. This feedback made the digital version better since the master thesis student could make changes to the software.

5.3.6 Conference Paper Submission and Review Results The Method Development Project

A paper was written simultaneously with the project. The paper consisted of a 10 page long report including all the important project activities and results. This report was sent to the International Conference of Engineering Design 2017 Committee. The title of the paper is: "ENHANCING THE BALANCING WHILE SYNTHESIZING-PROCESS - A METHOD DEVELOPMENT PROJECT" [9], and was accepted from the conference committee and will be presented in late August.

6
Discussion

This section is divided according to the method development regarding the "Functions Balancing"-step improvement and the digitalized BWS-process.

6.1 Discussion of the Concept Generation Result

The focus of the concept generation was to generate a broad set of ideas. This is seen with the diverse set of solutions presented in the results section. It would have been interesting if the concept generation had focused more on the visual elements of the process. Although some of the concept generation solutions presented interesting visual design elements it could have been set as a higher focus within the project. Arguably this may not have been feasible since the information of what visual elements the users of past research projects find desirable or not did not exist. This would have led to time being wasted in screening concepts and refining concept without any real data to back up arguments.

The selection and screening of concept was made by one master thesis student, one could argue that since there was only one person involved, the result could be biased. This would be countered by stating that since it was only one person grading each need with all the concepts the most fair grading process was achieved since the same through-process and mentality towards the grading process was applied.

The grades scores did not differ much between the winners and the second/third best scoring concepts. This could have been the result of a grade system which did not have an elaborate grade scale. All scores were given from one to three and the needs were weighted from one to three. Although the winner and the second scoring solution differed with 10 points arguably it would have been, if there was more time, a good idea to realize all the top three winning solutions when digitalizing the process. This would have been especially useful when assumptions had to be made concerning how hard or easy it would be to implement the solution while digitalizing the process.

6.2 Using Excel as the Software Package for Developing the Digital Version of the "Balancing While Synthesizing"-process

As Excel was deemed the best fit for the project, issues with the software became clear towards the end of the development phase. Microsoft Excel clearly is not primarily developed to create software like the BWS-process, since issues became apparent while working with the digitalizing. Excel is a powerful software and the digitalizing of the BWS-process may have been more demanding without it, as seen in the "Result"-section. But none the less, Microsoft Excel did require much programming intense action to be able to manipulate images within the software. This is something which is required of the BWS-process when dealing with images of sub-solutions between steps in the process. This was something that the master thesis student did not anticipate, as it was not a critical part of the whole process. The reason behind this is that, as mentioned in the "Methods"-section, the parts that make the basics of the process work were put in focus while digitalizing the process. The result was that images, in the current build of the software, are not automatically moved by the software. Instead users need to copy and paste the images to the desired location. As mentioned, this is not a critical function of the process, but for some users it may result in a slightly less intuitive process. With more time given or aiding consultancy of a professional Microsoft Excel programmer, the issue of manipulating images would be resolved as it is not impossible to achieve within Mircrosoft Excel.

6.3 Discussion of the "Functions Balancing"-Step Improvements

The changes presented make the tool more intuitive since it is sufficiently simplified making it easy to use and learn. As the tool acts within early stages of product development, concept generation stage, it is necessary to make the process easy to use while handling vague information [34]. This feature may further strengthen the tools applicability in industrial companies since its aim is to operate within vague information as stated by originator Almefelt (2005). One can argue that there is a quality loss present when simplifying the synergy assessment, but this could be countered by stating that it is an counteracting action to making decisions complex(like the old process was) when the goal is to operate within vague information since assumptions need to be made anyway(hence beneficial with a simple broad process). Generally open questions enable a more creative grading since the question does not specify a certain type of synergy and users are free to assess their best fitting constrains. Of course the users could be stimulated by the old synergy aspects as a way to guide the assessment if the new synergy assessment is too broad. It is of importance to create a project team with a diverse set of skills so the synergy assessment can be answered in the best way. This is based on the user needs found in the analysis of the KJ-method; "enabling networking" and "tool enables different competences". The old synergy analysis was only a process guiding the users through picking proper functions balances, but since the process welcomes iteration, all work was to waste since nothing was saved after the process ended. This could have made users feel confused and further make the process less intuitive. The new version grades the synergy for the overall concept giving the users an indication towards how well the concept preforms with its internals.

The winning sub-solution did not score perfectly among all the weighted needs. It got a low score while grading the solution in regards to the need called "B1" (Constraints are introduced later in process) found from Appendix A1. The reason is since the synergy assessment is introduced earlier in the process, users need to apply a certain amount of constraints to further progress. It received a lower score in regards to the need "H1", which is how easy or hard the solution would be to realize within a digital solution. The reason behind the lower score was that since it was a combination of two solutions it automatically received a lower score. The solution on the other hand performed very well when scored on the topic "A" which was "The tool brings people with different background together". This topic included needs such as networking and concurrent engineering. This was something that the solution excelled at since it incorporates simple and fast sub-solution balancing.

A finding from the analysis of the KJ-method was the need for a more diverse set of questions towards the synergy analysis such as design and cost, which automatically can be included now by the new version with its broad questions automatically satisfying the need. Criticism could be directed towards the assumption that needs to be made to form opinions on the synergy between functions. Generally this is something that always needs to be done when working with abstract processes such as concept generation. This means that even if assumptions are made, it will always be apart of concept generation if creativity is of importance. Since the steps within the BWS-process are less linear one could argue that the process is quicker to work through resulting in a shorter and faster process. Further strengthening the main areas first presented within section 1, especially to achieve shorter lead times through concurrent engineering.

In regards to the old BWS-process the synergy analysis was done after morphological matrix was made, this resulted in that the user had to work through it a second time. This could result in a less intuitive process since the "process flow" presented itself as an linear process, but involved users to go back a steps in order to progress. Something that is not present within the new structure of the "Functions Balancing"-step as the process sub-solution is called an aligned process.

Even though the "Stepwise With Cost/Performance Balance" sub-solution did not score as well as the top three solutions, it is still a very interesting concept. The reason is that it resonates well with the advantages and the basic philosophy of the BWS-process. The particular sub-solution makes the process shorter (which saves time) by combining steps but most importantly it focuses the Performance and cost assessment much earlier on. One should still not forget that the sub-solution introduces difficult aspects as well. The balance between performance and cost may be difficult for users to assess since it presents a different abstract question. It would be interesting if a remade needs list with new input and user feedback would made the result more favorable towards the "Stepwise With Cost/Performance Balance" sub-solution since it, as mentioned before, does have potential to achieve good results even though this project did not continue with the sub-solution.

6.4 Discussion of Digitalizing the "Balancing While Synthesizing"-Process

Through implementing the user's needs, interaction design and visual design-principles a successful digitalizing of the BWS-process was made. By using the different colours, the users gets an overview of the process and a sense of control. The hierarchical order and the numbering gives an easy idea of how to use the BWS-process. All steps have needed little interaction, which does not overwhelm the users and instead gives the users some freedom to operate with each other in-between steps of the process. This is exemplified by giving the users freedom to make up ideas for sub-solution by themselves according to the project teams and users preferences. Although the current version is not final, and only includes the basic functionalities of the process, it still gives a good understanding of the benefits it achieves which are the same as non-digital version hence inherit its advantages, basically being a one to one relation between them two. There are also some unique benefits to the digital version. Being a digital tool users can save time within the steps since everything is organized and automatically calculated. It is also supporting quick iteration, by just adjusting values within the synergy step, the end result is changed intuitively. Before the digitalized process, users needed big space allocated for the project (example discussing the morphological matrix with drawn images of sub-solution took up a whole wall), now the process only takes up a screen or a projector which could make the process more efficient. Drawbacks would be that perhaps physical media better supports creative work but one could argue that there is more time saved through quick and clean software and the digital version enables users, as stated before, use physical media for idea generation. The tool also supports starting activities by an introduction and terminology description, this is saving time which is something that could make an easier transition for the users towards using the tool moreover resulting in an easy to use process.

The current version of the software does not acquire fully dynamic capabilities. This is natural since the scope of the project was to develop a working digital version, the development had to focus on core mechanisms. This means that the current version only supports a set amount of performances which could be added to the process and many of the actions are restricted at the time. For example the figure 5.29 shows a window with the current performance profile added to the "balancing grade" window. This image is not dynamically changed, as users change performance profiles or update a performance. This function of having images dynamically update to the current performance profile would make the process more intuitive for the end users. But as mentioned, the project would not have been feasible whiteout the restrictions to the software as polishing and expanding on the core mechanisms would require a lot more time than the master thesis presented.
This digitalizing of the BWS-process has the potential to make industrial companies

with focus on new product development to save upon big investments since this tool is supporting; multi-disciplinary collaboration (Concurrent engineering), networking, work within vague information, performance/cost effective concepts, iteration and a synergy focus. In addition everything is developed to an easy to use and easy to learn-package. Users just need to open the excel-file and start the software if Microsoft Excel is already installed on the computer, making it ready to use within seconds.

A hidden need was interpret from the project member when constructing the needs list, number A1 from Appendix A1. This was the need of making the BWS-process into a online or cloud-based tool. Meaning a tool which team members could assess and work on simultaneously from different locations. This need was given a low grade when grading the needs which made it a low priority need. Moreover, it was interpreted as a "not feasible"-need in the project since it would require high level of programming. But if the tool would have been made into a completely online version some benefits could have been achieved. These benefits would further strengthen the concurrent engineering attributes of the improved BWS-process. This is because it would open up the possibilities for global teams to gain a practical concept and product development tool. This may resonance well with many industries as globalization is a real phenomenon [38]. Organizations need to adapt to global teams and it is becoming a rule rather than an exception. Since the enhanced BWS-process supports simpler decisions it would further supports an online versions, since it may not be of desire to make complex decisions when team members with valuable information are not in the same room. An online version would have a risk of reducing the capabilities to enabling networking between project member. The reason is that team members are not required be in the same location hence lowering the networking capabilities since the interaction would be of lower level while online.

7
Conclusion

The following section summarizes the master thesis project as well as presenting the future work potentials.

7.1 Conclusion

This paper presented enhancements of the "Balancing While Synthesizing"-process, a process which balances product properties while operating within early concept development. The objective of this master thesis was to, through method development, enhance a step in the process which was from the users point of view, less intuitive. In the subject of enhancing the process a digitalizing of the process was done with the same purpose; to further develop the tool.
Initially a pre-study was done which resulted in a user needs list. The pre-study involved analysis of past user interview answers and a theoretical research on relevant subjects. Different solutions for the less intuitive step were generated, the solutions were broad and achieved a creative span. The solutions were screened with the users needs list and the list was given different weights according to how important a specific need was. The new and more intuitive version of the BWS-process step presents a less data-dense procedure compared to the old one. The core principles of the new solution were to: 1) condense the user's alternatives and variables into a much lower complexity number to result in a faster process, 2) at the same time not loose the quality of the balances between product properties. 3) store the balances of product properties so when iterating the process, data and information are not lost. The new BWS-process is potentially a tool which could lower product development-project costs. Moreover, the easy balancing activity presented by the new process invites networking between project members as new and creative ideas are given space to emerge.

The digital version introduces a streamlined and easy to follow process which further strengthens the new "Balancing While Synthesizing"-process possibilities. The digital version is structured by visual design elements which guides the users through the process. The digitalizing process is focused on the core functions of the non-digital version and is structured in the same way. Speed, structure, flexibility and an iteration-friendly approach are all aspects which the digital version excels within. It was of importance to not counteract the non-digital accomplishments while creating the digital version, hence focus was on the needs list throughout the development.

Furthermore, on completion of the project a paper was written regarding the master thesis subject. This paper was submitted to the International Conference of Engineering Design 2017 Committee, and the paper was accepted by the committee in April 2017.

7.2 Future Work

To reach the results within this project much time and effort has been spent. There is still more future work to be done to refine and further develop the "Balancing While Synthesizing"-process.

Future work is needed to make the process more dynamic and improve the image manipulation capabilities within the digital version of the software. The improvement of the process and the digitalizing should be tested in a large scale study to examine their potential thoroughly with empirical data. Future work could also be put into making the digital version acquire a more refined visual design by breaking free from Microsoft Excel and developing the software within a less rigid software-package.

A suggestion of further improvements to the process would be to implement a logic that grades each function interaction of the synergy analysis and output data for the users showing for example which functions within the concept need more attention. The method development project did this for the concept as a whole but the opportunity to assess each step (in particular a problematic sub-solution) could be useful. Hence focusing the iterative steps on a product property with a low synergy grade.

Further method development on the "Balancing While Synthesizing"-process could include a seamless designed brainstorming activity for generating a morphological matrix. This is specially relevant when there now exists a digital version, since it could be implemented in the digital process.

Bibliography

[1] Almefelt, L., (2005) "Balancing Properties while Synthesising a Product Concept – A Method Highlighting Synergies", Proceedings of ICED'05, Melbourne, Australia, Paper Number 300.46.

[2] Alshamrani, A., Bahattab, A. (2015). A comparison between three SDLC models waterfall model, spiral model, and Incremental/Iterative model. International Journal of Computer Science Issues (IJCSI), 12(1), 106-111.

[3] Appspro.com. (2017). The XY Chart Labeler Add-in. [online] Available at: http://www.appspro.com/Utilities/ChartLabeler.htm [Accessed 1 Jan. 2017].

[4] Barbara Davis Darren Radford., (2014). Going Beyond The Waterfall: Managing Scope Effectively Across the Project Life Cycle. J. Ross Publishing.

[5] Brainstorming.co.uk. (2017). Brainstorming rules, software and free training. [online] Available at: http://www.brainstorming.co.uk/toolbox/brainstormingtoolbox.html [Accessed 5 Jan. 2017].

[6] Controleng.com. (2016). Fundamentals of cascade control | Control Engineering. [online] Available at: http://www.controleng.com/single-article/fundamentals-of-cascade-control/bcedad6518aec409f583ba6bc9b72854.html [Accessed 30 Dec. 2016].

[7] Cooper, A. and Reimann, R. (2003). About face 2.0. 1st ed. New York: Wiley.

[8] Dybå, T. and Dingsøyr, T. (2008). Empirical studies of agile software development: A systematic review. Information and Software Technology, 50(9-10), pp.833-859.

[9] ENHANCING THE BALANCING WHILE SYNTHESIZING-PROCESS - A METHOD DEVELOPMENT PROJEC. 2017 Proceedings of ICED'17.

[10] Griffin, A. and Hauser, J. (1993). The Voice of the Customer. Marketing Science, 12(1), pp.1-27.

[11] The second Toyota paradox: How delaying decisions can make better cars faster. (1995). Long Range Planning, 28(4), p.129.

[12] Keinonen, T. and Takala, R. (2006). Product concept design. 1st ed. [New York]: Springer.

[13] Kesselring, F., (1951) "Bewertung von Konstruktionen" (Evaluation of Designs) (in German), Deutscher Ingenieur-Verlag, Düsseldorf, Germany

[14] Lance, D. (2006). Creating an affinity diagram. LL Decker Associates, Inc., Helping organizations change.

[15] Lyons, Chopeta, and Ruth C. Clark. Graphics for Learning, edited by Chopeta Lyons, and Ruth C. Clark, Wiley, 2010.

[16] Lowgren, J. and Stolterman, E. (2004). Thoughtful interaction design. 1st ed. Cambridge, Mass.: MIT Press.

[17] Moggridge, B. (2007). Designing interactions. 1st ed. Cambridge, Mass.: MIT Press.

[18] Nonaka, I. and Takeuchi, H. (1995). The knowledge-creating company. 1st ed. New York: Oxford University Press.

[19] Norman, D. (1988). The psychology of everyday things. 1st ed. New York: Basic Books.

[20] Pascal.computer.org. (2016). Search Form. [online] Available at: https://pascal.computer.org/sev$_d isplay/index.action[Accessed 22 Nov.2016]$.

[21] Preece, J., Rogers, Y. and Sharp, H. (2002). Interaction design. 1st ed. New York, NY: J. Wiley Sons.

[22] Pugh, S., (1990) "Total Design. Integrated Methods for Successful Product Engineering", Addison-Wesley Publishing Company, Wokingham, UK

[23] Gamasutra.com. (2016). Gamasutra - Making Lean Startup Tactics Work for Games. [online] Available at: http://www.gamasutra.com/view/feature/168647/making$_l ean_s tartup_t actics_w ork.php?print = 1[Accessed 22 Nov.2016]$.

[24] Hatchuel, Armand (1996). Théories et modèles de la conception, Cours d'ingénierie de la conception. Paris: École des Mines de Paris.

[25] Hatchuel A., Le Masson P. Weil B. (2004), C-K Theory in Practice: Lessons from Industrial Applications, 8th International Design Conference, D. Marjanovic, (Ed.), Dubrovnik, 18–21 May 2004: 245–257.

[26] Heartharena.com. (2016). Hearth Arena - Beyond the tierlist. [online] Available at: http://www.heartharena.com/overwolf [Accessed 30 Dec. 2016].

[27] Pahl,G.,Beitz, W. (1996) Engineering Design, 2nd edition, Springer-Verlag, London.

[28] Peltier Tech Blog. (2017). Variable Width Column Charts (Cascade Charts) - Peltier Tech Blog. [online] Available at: http://peltiertech.com/variable-width-column-charts/ [Accessed 1 Jan. 2017].

[29] Proctor, T. (2005). Creative problem solving for managers. 1st ed. London: Routledge.

[30] Peters, D. (2014). Interface design for learning. 1st ed. [San Francisco, CA]: New Riders.

[31] Pimmler, T. U., Eppinger, S. D., "Integration Analysis of Product Decompositions", Proceedings of ASME, DTM '94, DE-Vol. 68: pp. 343-351.

[32] Saffer, D. (2010). Designing for interaction. 1st ed. Berkeley, CA: New Riders.

[33] Ulrich, K. and Eppinger, S. (1995). Product design and development. New York: McGraw-Hill.

[34] Ullman, D. (2003). The mechanical design process. Boston, Mass.: McGraw-Hill.

[35] Winroth, M. och Säfsten, K. (2016) Manufacturing strategy investigation - Application of the STRATEGO-tool.

[36] Winograd, T. (1997) From Computing machinery to interaction design. In P. Denning and R.Metcalfe (eds), Beyond Calculation: The Next Fifty Years of Computing. Springer-Verlag, Amsterdam, pp. 149-162.

[37] Wheelwright, S. and Clark, K. (1992). Revolutionizing product development. New York: Free Press.

[38] Zander, L., Mockaitis, A. and Butler, C. (2012). Leading global teams. Journal of World Business, 47(4), pp.592-603.
[39] Zwicky, F. (1966). Entdecken, Erfinden, Forschen im morphologischen Weltbild. Munchen: Droemer/Knaur.

A
Appendix

A.	Need	Weight	Sub-Solution Name:	Stepwise with cost/Perf. balance	Simple With Grading	All design parameters with gradin	Flow-step images	3-Axis	Aligned process	Seperated design parameters	DSM synergy	CK-synergy	Cascade Synergy	3 option method	Super AI (artificial intelligence)	Old method (the functions balancing step prior to the project)	Aligned with grading	Simplegrading with Flowstep images	Flowstep images with alligned process
The tool brings people with different backgrounds together	1 The tool enables networking	2		1	2	3	3	2	3	2	1	2	3	3	1	3	3	2	3
	2 Enables Concurrent engineering	3		2	3	2	3	2	3	2	2	2	3	3	3	3	3	2	3
	3 Shorter leed times (saves time)	3		3	3	2	2	2	3	2	2	2	2	2	3	3	3	2	2
	4 The tool enables different competences	2		1	2	3	3	2	3	1	2	2	3	3	1	2	3	3	3
	5 The tool shows "others" basis	1		1	2	3	2	1	3	1	1	2	2	2	1	2	3	2	2
B.																			
The tool does not prohibit users with design constraints early	1 Constraints are introduced later in process	2		1	2	1	1	3	1	3	2	2	1	2	3	3	1	1	1
	2 Innovative concepts result	3		1	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2
	3 Cost effective concept	3		3	2	3	2	1	3	3	3	2	2	3	3	3	3	3	2
C.																			
The tool prioritises solutions - innovation focus	1 Focus on setting up the targets from the start of the process	3		2	2	2	2	2	2	2	2	2	2	2	3	3	3	2	2
	2 Does not go through all possible solutions	3		3	2	3	3	2	2	2	2	3	1	3	3	3	3	2	2
	3 Enable iteration for users	3		3	3	3	3	3	3	3	1	1	1	2	3	2	3	3	3
D.																			
The Synergy step is easy - low info in reason, bad communication was not it so badly executed	1 Simple procedures	3		3	2	1	2	3	2	3	1	1	1	2	3	1	3	2	2
	2 Overview of Synergy process	3		1	3	3	3	1	3	2	2	3	1	3	1	3	3	2	3
	3 The tool provides start up exercise	1																	
	4 (The tool is effective - what would it mean dont know)	2																	
	5 Show the criterias on each step STATIC	3		2	3	3	3	1	2	1	1	3	1	3	1	3	2	3	3
	6 Show the synergy grade for current step (Dynamically for each step)	3		1	2	2	3	1	3	1	3	1	2	2	3	1	3	2	3
	7 More/Different aspects to seek synergy between	2																	
	8 Show current solution (additive for each subfunction Dynamic)	3		3	2	2	3	1	3	2	1	1	1	3	2	3	3	3	3
E.																			
Digitalizing the tool	1 Enable work from different locations	1!																	
	2 Fast process (The time it takes to finish the process)	3		3	2	1	2	2	2	2	1	1	1	1	3	2	2	2	2
	3 Outputting Preformance/cost-effective results	3		3	2	2	1	2	2	2	2	2	3	3	3	3	3	2	2
	4 Outputting innovative results	3		2	2	2	2	2	2	2	1	3	2	3	3	3	2	2	2
	5 Can handle all pats of the BWS-process	3																	
	7 Does not demand too much CPU power - Slows down process	3																	
	8 Is a stable software version	3																	
F.																			
How users experince the tool	1 Description text of each tool in each part	3																	
	2 The tool steps are easy to remember	3		3	3	2	3	2	1	2	2	2	2	2	3	1	2	3	2
	3 Small steps - not overwhelming	2		3	2	1	3	3	2	2	1	1	2	2	3	1	2	2	2
	4 Gives visual feedback	1		2	2	2	3	3	3	1	2	2	2	1	3	2	3	2	3
	5 Easy to learn	2		3	3	2	2	3	3	2	2	1	2	2	2	1	3	3	3
G.																			
The tool does not take too long to perform	1 To complete the whole process does not take too long time	3																	
	2 Sub-steps does not take too long time to preform	3		3	3	2	2	3	2	2	1	1	1	1	3	2	2	3	2
Excended																			
H.																			
Software needs	1 Easy to realise (to make logic and program)	3		2	2	2	2	1	2	2	1	1	1	2	0*	2	1	1	1
	2 Does not reqire excensive work to make the process work(installment etc)	3		2	2	2	2	1	2	2	1	1	1	2	0*	2	2	2	2
			TOTAL:	156	161	148	164	132	162	139	112	120	122	138	0	153	174	155	158

Figure A.1: The weighted needs list with the different weighted sub-solutions.

1. ACTA Advantage
2. Axon Idea Processor
3. Brainstorm
4. BrainStormer
5. Brainstorming 1.0.1
6. Brainstorming Toolbox
7. CK Modeller
8. CM/1
9. ComedyWriter
10. Concept Draw
11. Corkboard/Three by Five
12. CreaPro
13. Creative Whack Pack
14. Creative Studio
15. Decision Explorer
16. Dramatica
17. DynoNotePad
18. Genius Handbook
19. GroupSystems
20. Grouputer
21. Idea Generator Plus
22. IdeaFisher
23. IDEGEN++
24. In Control
25. InfoDepot
26. Innovation Toolbox
27. Inspiration
28. Invention Machine
29. MaxThink
30. MicMac
31. Microsoft Word (Outlining Feature)
32. Microsoft Word (Thesaurus Module)
33. Mind Mapper
34. MindMan
35. MoonLite
36. MORE
37. Paramind
38. Personal Best 3.1
39. Plot Prompt
40. Plots Unlimited
41. Powerpoint
42. Scriptware
43. Serious Creativity
44. Simplex
45. Sirius
46. StoryBuilder
47. StoryCraft
48. StoryCraftNet for Writers
49. SuperMemo
50. The Creativity Machine
51. The Electric Brain
52. The Electric Mind
53. The Solution Machine
54. Thoughtline
55. Thoughtpath
56. TreePad
57. Turbo Thought
58. Visimap / InfoMap
59. VisionQuest
60. Visual Outliner
61. WinGrid
62. WordPerfect
63. Yeahwrite

Figure A.2: Creative idea.

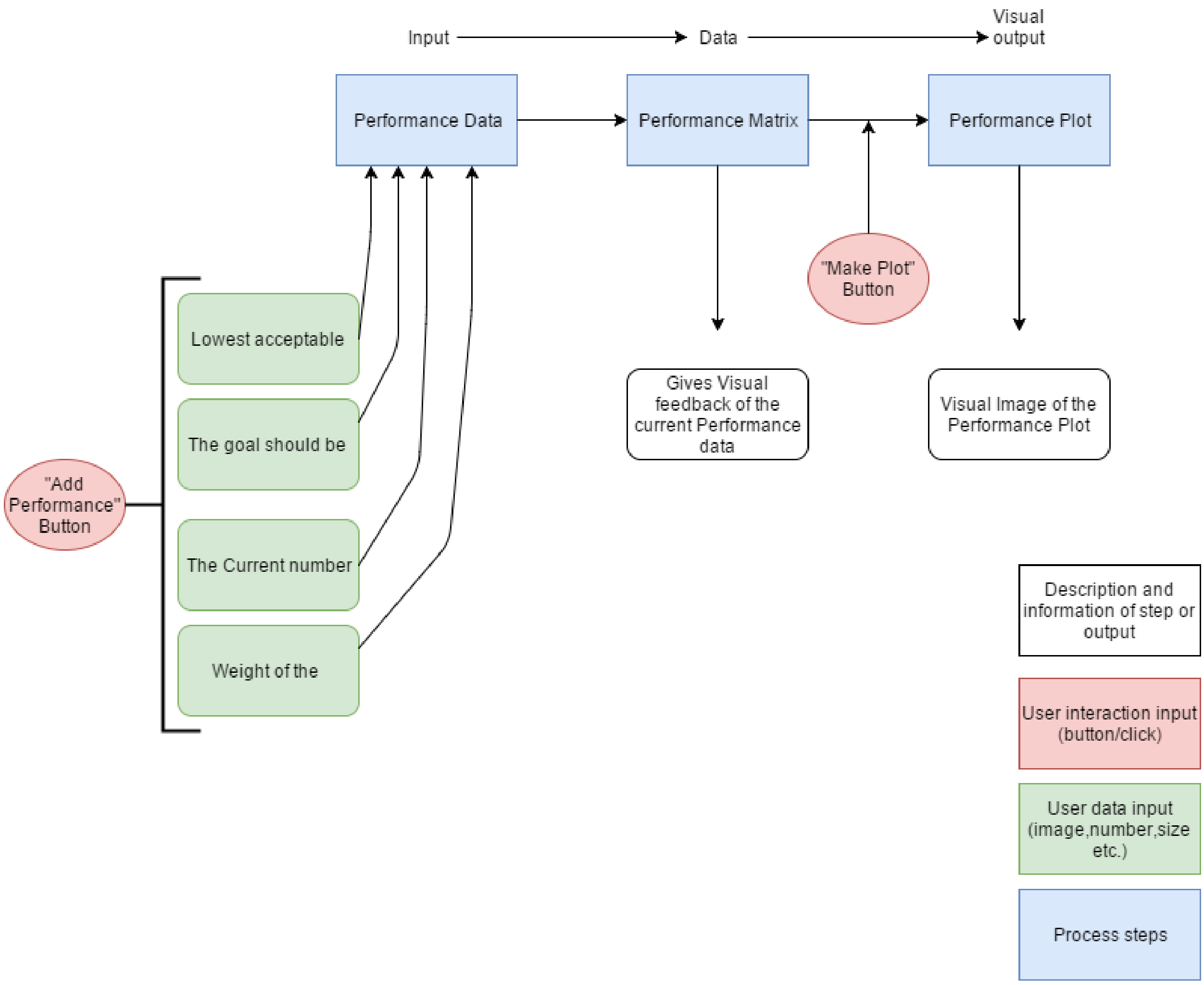


Figure A.3: The flowchart of the performance profile creation step.

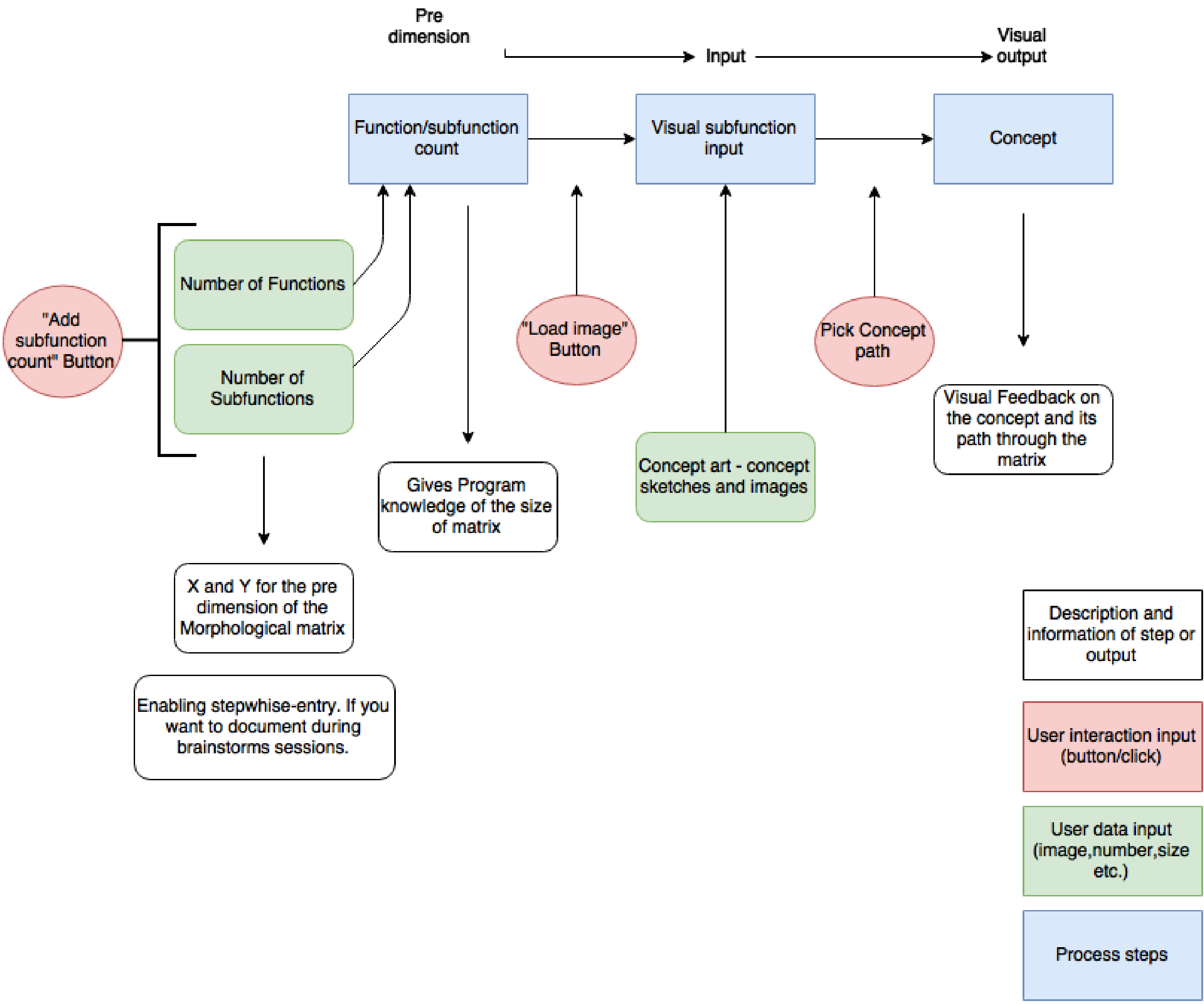


Figure A.4: The flowchart of the morphological step.

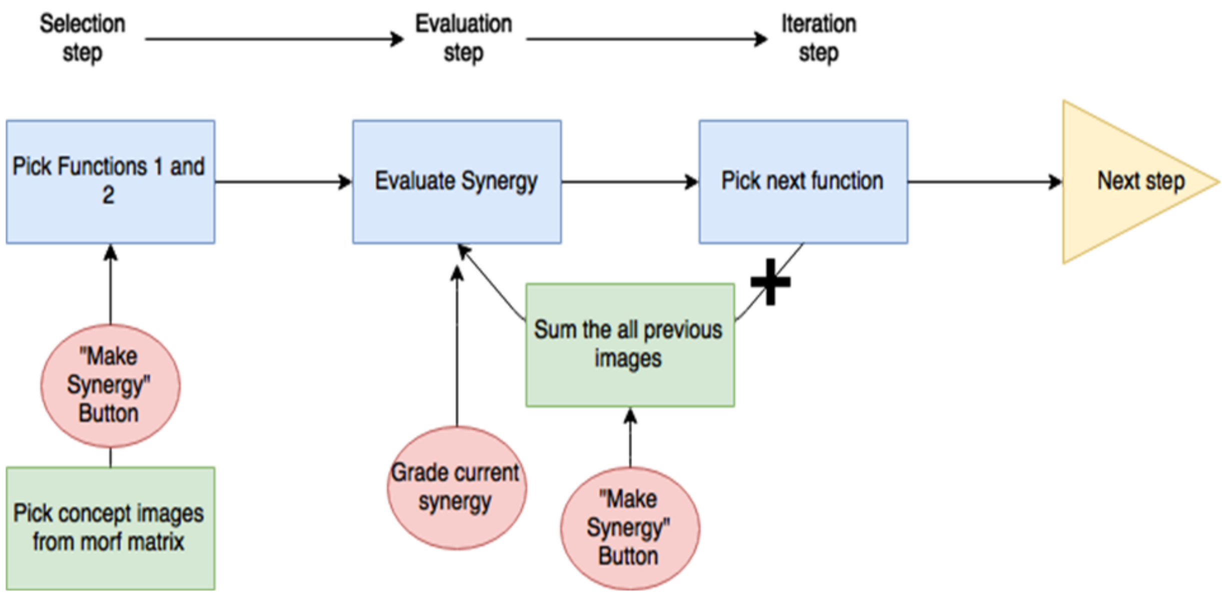


Figure A.5: The flowchart of the synergy step.

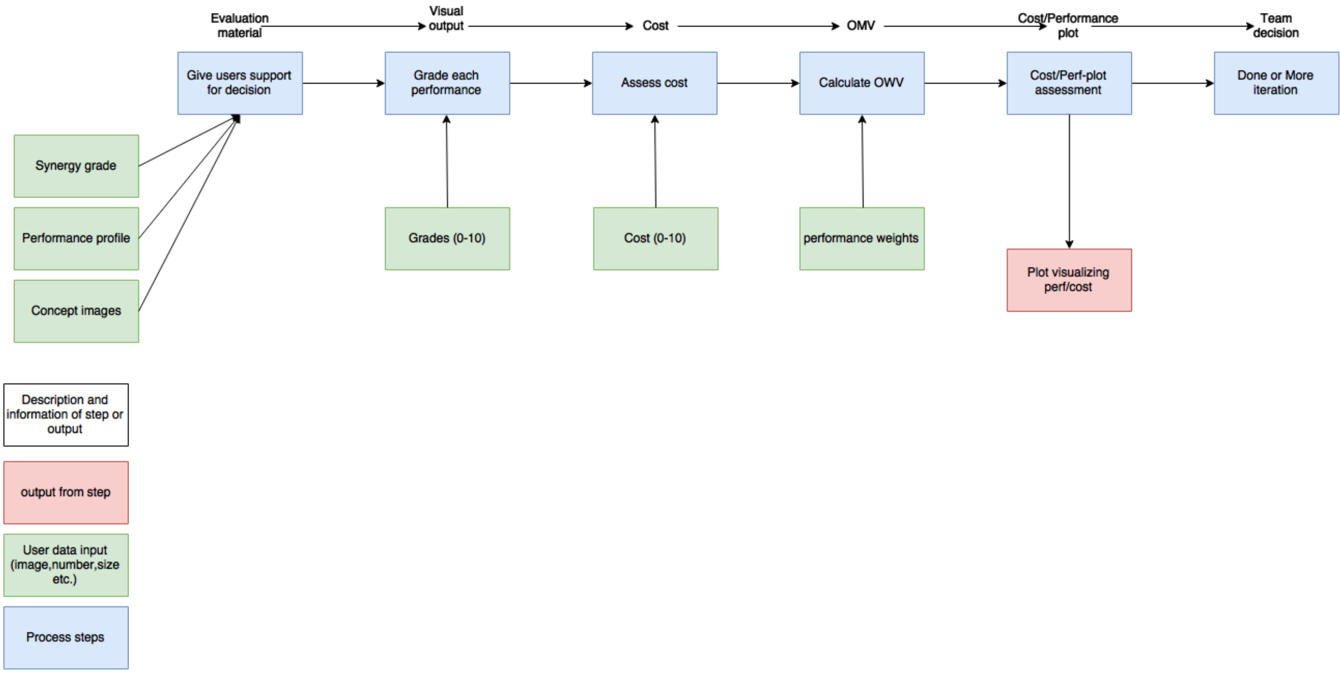


Figure A.6: The flowchart of the evaluation step.