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ENHANCING THE BALANCING WHILE SYNTHESIZING-PROCESS - A METHOD DEVELOPMENT PROJECT

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Abstract

There exist many different product and concept development methods. Many of these do not target the performance and cost-balance between sub-solutions in a concept. The management of properties between sub-solutions do yield value in a cost-effective way since not all solutions for a concept is investigated. Moreover, there is a risk of conflicts between sub-solutions which can lead to costly loops. A concept development method, Balancing While Synthesizing-process was developed in the purpose to support balancing activities. Results from research projects showed one step in the process not being intuitive enough and further development was needed. A method development project was conducted to make the particular step more intuitive. The project also includes a digitalization of the process with the goal to achieve further improvements. This paper describes the enhanced version of the Balancing While Synthesizing-process and the benefits achieved realized by the method development.

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

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1 INTRODUCTION

Developing new ideas and iterating on existing ideas is one of the key activities that made humans across history enhance their living standards and improve the world around them, this gives product development its importance. 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 to implement their ideas in a feasible fashion. Today, there is a lot of different product development methods and tools used in the industrial and in the academic world. One of these methods is the "Balancing While Synthesizing"-process (Almefelt, 2005). In this work, the abbreviation “BWS-process” is used. The BWS-process was first made public in 2005 (Almefelt, 2005). The process is acting within the Concept Development phase, in regards to the Ulrich and Eppinger (1995) generic product development process. Balancing, which is one of the core principles of this process, is defined by management of properties of a product concept in order to provide user value in a cost-efficient way. Balancing between performance and cost properties can, for project teams, be a challenging act (Almefelt et al., 2003). According to Almefelt (2005) the goal and core advantages of the process is: Enable concept development with vague information. Enable cross-functional work in teams (shorter lead times, less cost and time-consuming iterative loops). Focus attention on synergies between sub-solutions. Evaluate overall performance in a performance/cost-ratio.

Thus, the method finds the appropriate concept while not examining the millions of concept solutions that possibly could exist. The task of balancing performance and cost is a challenging task, especially when done in an early stage of a product development process, since information is low at this stage (Ullman, 2003). The tool has been part of two major studies were promising result was accomplished, regarding both how the users experience with the tool, and the outcome itself. The tool showed opportunities for improvement regarding a step in the process where users experienced the step less intuitive and hard to understand, in some cases skipping the particular step completely. This meant that this project needed to focus on how to solve these issues by first finding the underlying reason and how to improve the process through method development and interaction design. Thus, resulting in the first objective which is to make the particular step more intuitive. 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, thus resulting in the second objective.

1.1 The "Balancing While Synthesizing"-process prior to the method development project

The BWS-process, before conducting the method development project, is presented here. The process is illustrated in Figure 1 and this section will go through the process according to each step in Figure 1. Step 1 is the step where the performance profile is specified. In this context a "performance" is a certain target for the project; each performance is given a weight, a goal and a current grade. Constructing a profile amongst all the performances gives users a good overview and sense of the goal. Step 2 is made up by constructing a general proposal of sub-solutions for the product in development. This step is the creation of a morphological matrix (Zwicky, 1966), which is a matrix consisting of different sub-solutions proposals for the functions making up the product. The function with the most interaction is arranged to be on the top, this is step 3 in the process. Almefelt (2005) describes this step as: "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 ". Users pick one promising solution from each row while adding all solutions together a concept solution is created. Step 4, also referred as the "functions balancing"-step in this project, is the step with most focus on the method development project. The step is coloured red in Figure 1 since it is the step where the first objective targets. It starts the first sub-solution (the one on the first row of the morphological matrix) and the second sub-solution. After that conducting a synergy analysis made up by giving a grade, according to the synergy between the sub-solutions. The grades are composed by a four grade scale: conflict, no synergy, medium synergy and high synergy. The analysis is done on each performance from the performance profile and engineering properties (Manufacturing, Material and Geometry). When all sub-solutions are added together from each row, a system concept is created. Finally, Step 5 is the step where the evaluate concept is made. The concept is now ranked within the performance profile and each is part of the concept is assumed a production cost. The score from the performance profile is added up with their specific weights and cost, then finally put into a performance/cost plot which gives the users a direction to how well the concept scored. If the users are satisfied with the result the process ends here, if not step 4 and 5 are repeated until a desirable performance/cost score is achieved.

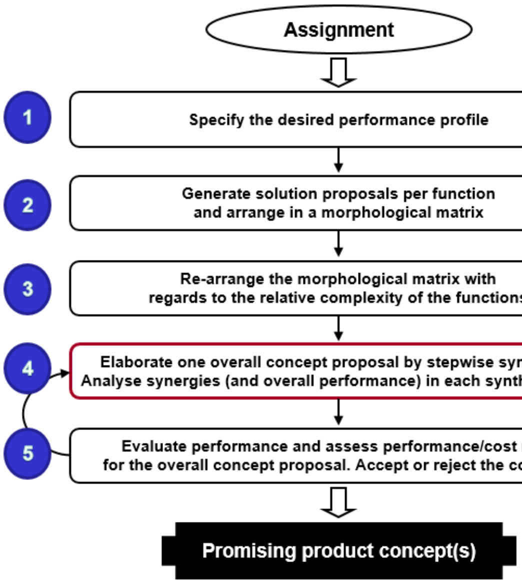

Figure 1. Overview of the "Balancing While Synthesizing"-process Almefelt (2005) - each number equals a step in the process

2 RESEARCH APPROACH

The approach of the project was divided into two steps according to the two objectives, these have been making the improvement for the "functions balancing"-step, step 4, and digitalizing the process.

2.1 The approach towards the "functions balancing"-step improvement within the "Balancing While Synthesizing"-process

The process used for the method development is based on the general product development process, Ulrich and Eppinger (2003). Developing processes with focus on ease of use (interaction design) share similar a process, which made the decision of picking the Ulrich and Eppinger-based method relevant since it was a more commonly known method for the project member (Preece et al., 2002). The method development of the "functions balancing"-step consisted of four steps:

- A research step containing an analysis inspired by the KJ-method from interviews (Lance, 2006) conducted through past studies, literature review and analysis of similar methods and tools.
- Creation of a user needs list, where each need later got a weight according to importance of the need based on the result from the KJ-method, literature study and project objectives.
- Generating a broad set of solutions of how to solve the "functions balancing"-step. Questions to generate ideas were asked, such as; Why did the user find the tool less intuitive? Was it because there were too many steps? Was it too many things to keep in mind at the same time?
- Weighting the solutions against the user needs list and deciding the winning concept. To remove bias opinions when screening solutions, the project member used the user needs list to each sub-solution.

2.2 The approach towards digitalizing the "Balancing While Synthesizing"-process

The method for digitalizing the BWS-process, on the other hand was based upon the waterfall method (Davis and Radford, 2014), the approach was scaled down, compared to a full waterfall method and consisting of four steps: Requirements, Design, Implementation and final testing. The requirements for the digitalization were achieved from the user needs list, referring back to the previous subsection, an addition was made by adding software specific design guidelines from the theory study on interaction design. The design phase was made up by creating simple flowcharts showing the interaction, input and output for each step in the improved BWS-process. As well as input from the interactions design theory in the form of the design and visual design guidelines both supporting an easy to use and easy to learn software. Interaction design guidelines were made up by (Norman, 1998);

- Visibility – for example knobs, users know what to do to make it work.
- Consistency - Restricting user interaction in a given time.
- Affordance - using the same elements for tasks of similar activities.
- Affordability - The element itself gives the user an idea of what to do with it.

The visual design theory teaches that different saturation, size and depth can guide user interactions with the tool to make it more intuitive and by demand less on a subconscious level, resulting in an enhanced learning and using experience (Peters, 2014). The implementation phase was based upon implementing the most critical parts of the tool, meaning focus was on the relevant parts and overall functionality of the BWS-process (Preece et al., 2002) Picking the right software package for digitalizing the BWS-process was constructed by criteria for the software and selecting different options. The criteria was made up by factors such as programming language barriers, future development factors, implementation methods, aesthetics and accessibility for the end users. The different options were later put into an elimination matrix which lead to picking MS Excel and it's VBA-programming.

3 METHOD DEVELOPMENT: RESULT OF THE "BALANCING WHILE SYNTHESIZING"-PROCESS IMPROVEMENTS

This section is divided up in two parts, the first one going through the enhancement of the BWS-process itself and the second part going through the result regarding the digital version.

3.1 The proposal for a new and improved "Balancing While Synthesizing"-process

This section describes the improved version of the BWS-process with the goal to make the "functions balancing"-step more intuitive and further strengthen the core advantages of the process. The enhanced framework is shown by Figure 2, the basic principle of the new BWS-process is that it is not a linear process, instead the "functions balancing"-step is done in a more parallel fashion, clearly visible in Figure 2. This means that the users do the balancing between functions instantly when adding functions together from the morphological matrix. It is noteworthy that this makes the process clearer, increase consistency as well as a constraint towards what users should do at each step. One of the core research questions was indeed 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: Condensing the user's alternatives and variables. Simultaneously not losing the quality of the synergy assessment. Finally, storing the balancing activity so when iterating the process, data and information is not lost. The following subsections will present each improvement in more detail.

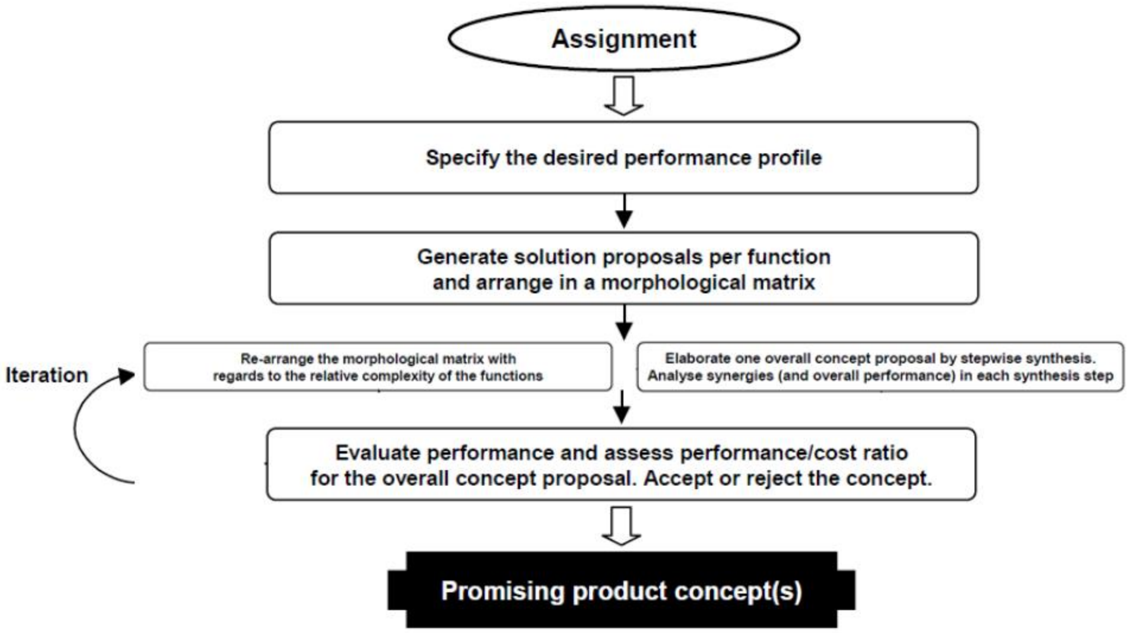

Figure 2. Overview of the improved version with "Balancing While Synthesizing"-process with improved "functions balancing"-step. Based on the figure from Almefelt (2005)

3.1.1 The enhanced "Balancing While Synthesizing"-process

Focus on the section will be on presenting the changes of the "functions balancing"-step and the concept evaluation step, not the whole BWS-process. The reason is that, as seen in Figure 2, there were no changes to the process before the "functions balancing"-step. The section borrowing visual representations from the digitalization of the process since it gives a clear presentation of the steps, the focus is still on the process and not on the digitalization. After generating sub-solutions for each function within the morphological matrix users arranging the matrix so the function with the most interaction is at the top, see the most left side of Figure 3. When this is done it is possible to start upon the "functions balancing"-step. The balancing step is made up by a selection phase and an evaluation phase and iteration between these two steps until the synergy steps are over. The synergy steps are made up of the number of functions minus one, seen in Figure 4. Starting off with the selection phase which is made up by first picking a sub-solution amongst the first row of functions and a second sub-solution from the second row, this action is illustrated in Figure 3 marked with the number "one" on the red arrow. The selected sub-solutions are then put side by side so the user achieves a visual overview, this can be seen in Figure 4. The left part of the image, under the column “Solution(s) sum” is where the current sum of all function is placed. On the right side under the column “Synergy balance with next function” the sub-solution who is current undergoing analysis is shown.

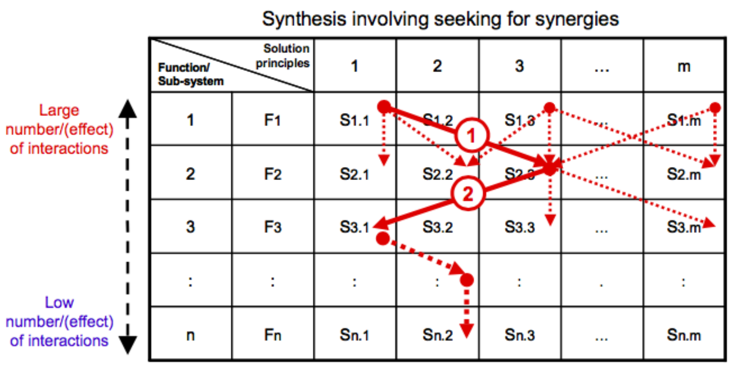

Figure 3. Morphological matrix showing sub-solution combination (the red arrows with the numbers as selection steps) and the left side of the figure states the interaction level Almefelt (2005)

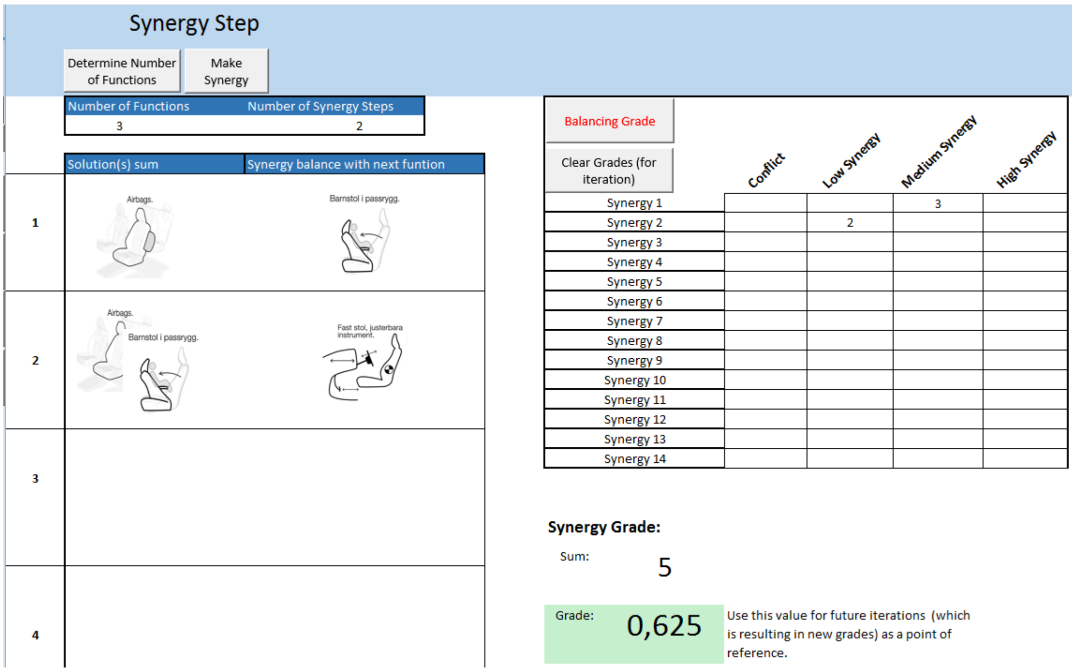

Figure 4. Overview of the "Synergy Step". Upper right side showing the number of functions and the amount of synergy steps. The balancing grade is given by pressing the button with the red text "Balancing Grade" which shows a pop-up window as displayed in Figure 5.The synergy grade is given in the green square on the bottom of the right side

The synergy analysis itself is constructed by giving a grade while comparing the “Solution(s) sum” to the “Synergy balance with next function”-column. This part is occurring to the right side of Figure 4, in the section called “Balancing Grade”. This new synergy analysis is just made up by the four grades, as seen in Figure 5. Users can now put a cross for the correct synergy grade when comparing the sub-solution with each other, note the low amount of complex decision-making. The users can read about the performance profile and engineering properties if more input is needed as a supporting activity. The next step is to pick the next sub-solution for the next synergy analysis, this is illustrated by the second row (the left side) of Figure 4. Again users pick a sub-solution from the morphological matrix but this time only one function from row three. The selected sub-solution is then compared to the sum of the sub-solution selected before. A new synergy analysis is made and users grade the functions within the “Balancing Grade” section again. 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 are 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 well the overall synergy was after a synergy assessment hence a synergy grade. Moreover, each balancing grade maps to a score from zero to three (Conflict=1, Low Synergy=2, Medium synergy=3 and High Synergy=4) see Figure 4 for an example. 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 in an output that is not wasted between iterations (if compared to the old "functions balancing"-step with the new process) since it now is a value saved for comparison. The synergy grade is not important on its own if not compared with a concept made from a new iteration.

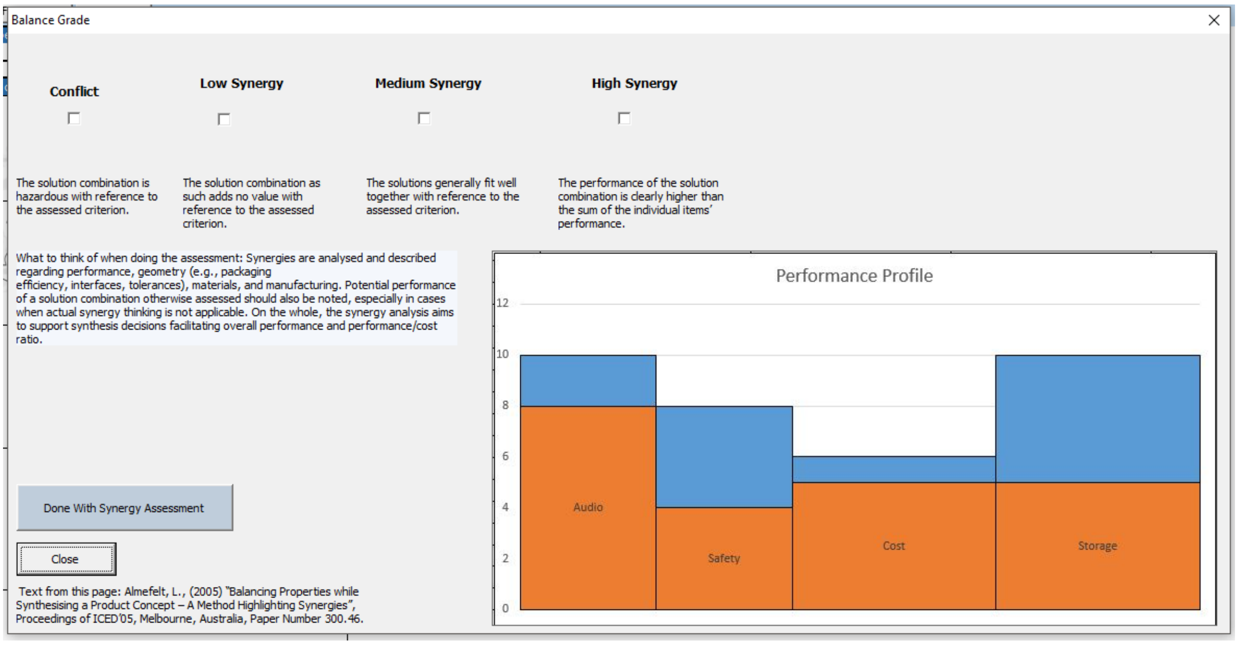

Figure 5. The Balancing Grade assessment pop-up window which shows when users press the "Balancing Grade"-button from Figure 4

3.1.2 The digital version of the "Balancing While Synthesizing"-process

As seen in Figures 6 and 7, the BWS-process was successfully digitalized within the standard software Microsoft Excel. The main process of the digitalization is one to one with the improvements presented in the subsection above. The users follow the description of each step in a chronological order to complete the process. Just like the non-digital version the users first construct a performance profile by adding the metrics for all the performances (see Figure 7 for a representation of this step). Afterwards, a morphological matrix constructed by just pressing a button. The assessment of the synergy is made just like what was described in the section above regarding the synergy assessment. And finally the performance/cost-plot (see Figure 6 for an overview of this step) is generated according to how the users grade each performance alike the original description in Section 1, step 5.

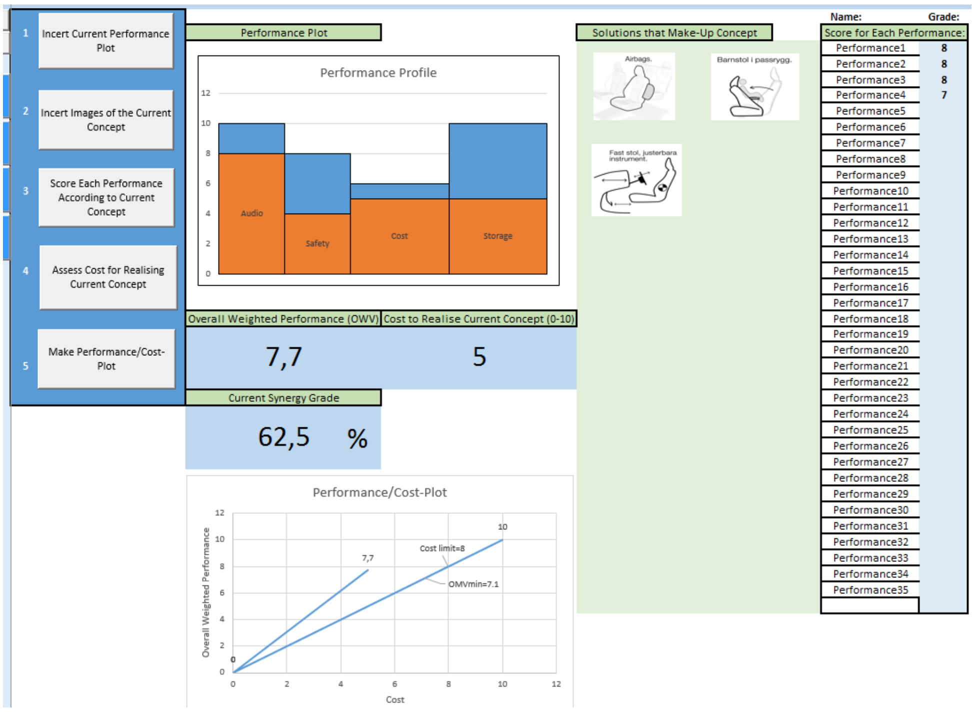

Figure 6. The final assessment of the concept showing the Performance profile, images of the concept and lastly the final plot of graded concept within a Performance/Cost-Plot

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 7, the green section is the "overview section", and the orange part is the "actions section". The "overview section" contains a rigid set of elements which are constrained and do not change while using the BWS-process. Moreover, the 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 constructed 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 of the BWS-process, requiring a larger portion of the available screen space.

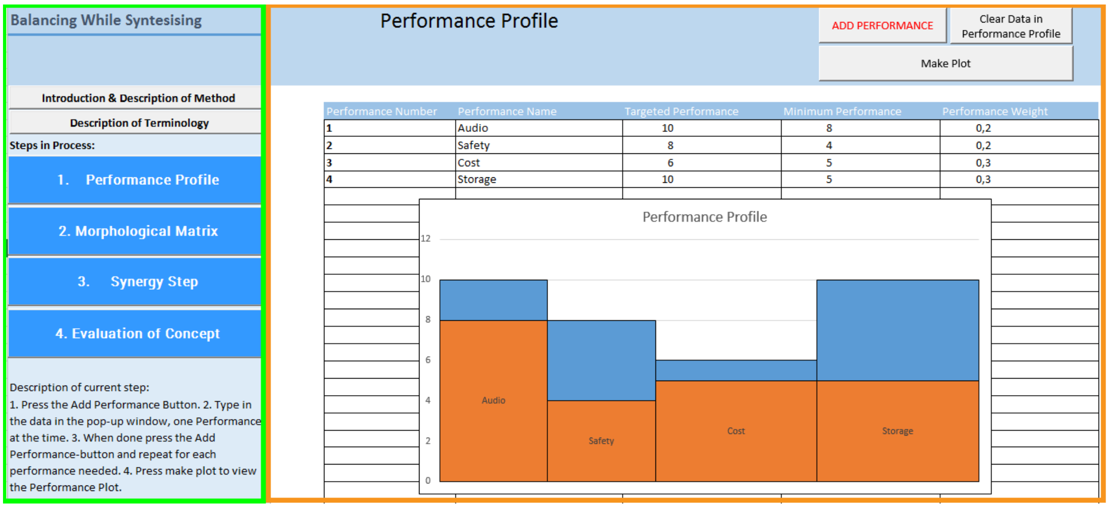

Figure 7. Showing the "overview section" (green) and the "action section" (orange) layouts of the digital "Balancing While Synthesizing"-process. The images is from Step 1 within the process, which is called "1. Performance Profile"

4 DISCUSSION

The discussion section is divided according to the method development regarding the "functions balancing"-step and the digitalized BWS-process.

4.1 Discussion of the "functions balancing"-step

The changes presented does make the tool more intuitive since it is sufficiently simplified making it easy to use and learn. As the tool is acting within early stages of product development, being the concept generation stage, it is key to make the process easy to use while handling vague information (Ullman, 2003). This feature may further strengthen the tools applicability in industrial companies since its aim is to operate within vague information as stated by originator Lars 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 counteracting to making decisions complex when the goal is to operate within vague information since assumptions need to be made anyway. Since the synergy analysis now is asking a very broad question, being the overall synergy instead of specific design or performance metrics, 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. 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; "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 performs with its internals. 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 a part 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.

4.2 Discussion of digitalizing the "Balancing While Synthesizing"-process

Through implementing the user needs, interaction design and visual design-principles, a successful digitalization of the BWS-process was made. By using the different colours the user gets an overview of the process and a sense of control. The hierarchal order and the numbering gives an easy idea of how to use the BWS-process. All steps in the process require simple 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. Although the current version is not final, and only includes the basic functionalities of the process, it does still give 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 does also support 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. As Microsoft Excel is a software package made for calculations it did present itself with issues regarding the manipulation of images within the software. This yielded time consuming VBA-programming which and required programming skills which the project member did not have. At the moment, the users need to copy and paste images by their own while using the software. This may not be a big issue since one could argue that the action of copy and pasting is one general basic operation when working with digital mediums. But none the less, a more automatic and dynamic medium is often a more intuitive and easy to learn process. This digitalization of the BWS-process build upon the already existing benefits presented in the first section as well as the additions from the "functions balancing"-step improvement. The digitalization has the potential to make industrial companies with focus on new product development to save upon big investments since this tool is showing capabilities of supporting; multi-disciplinary collaboration (Concurrent engineering), networking, work within vague information, performance/cost effective concepts, saving time, cost, iteration speed 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.

5 CONCLUSION AND FUTURE WORK

This paper presented enhancements of the "Balancing While Synthesizing"-process, the tool includes synthesis amongst product properties while operating within early concept development. Further development of the tool was made in the first place since past studies showed users finding one step in the process less intuitive. The purpose to achieve an overall enhancement through digitalizing the process was also made. While observing the purpose of the method development project and the result achieved one can conclude that the method development of the "Balancing While Synthesizing"-process do now support a more intuitive process. Achieved by the creation of a simpler synergy assessment, and a shorter process by making the process less linear. The process as a whole is after the method development project shorter, hence easier to understand and faster to perform. The less detailed synergy analysis has potential to enhance the already existing support for multi-disciplinary collaboration and networking. This is enabled by the broad questions, which invites all departments of product development to assess their opinion emphasizing networking between the project members and an invitation towards creative thinking. The digital version of the BWS-process shows promising capabilities of saving time, cost and iteration speed while keeping a clean, easy to learn and intuitive process for the users. Achieved by merging the theory from interaction design and visual design to a practical software package. Future work would be needed to make the process more dynamic and improve the image manipulation capabilities within the digitalization. The improvement of the process and the digitalization should be tested in a large-scale study. Although one could argue that a process with fewer steps is more intuitive, it would be nuanced with empirical data. Future work could also be put into making the digital version acquire a more refined design. 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 what function within the concept need more attention. The method development project did do this for the concept as a whole but a potential for assessing each step (in particular a problematic sub-solution) could be useful. Hence focusing the iterative steps on a sub-solution with a low synergy grade.

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