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DESIGN METHODOLOGY APPLIED FOR PRODUCT INNOVATION IN A MULTI-DISCIPLINARY PROJECT – A CASE STUDY

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Abstract

This paper takes its departure in the results of a research project aiming to develop resource-economic and lightweight car concepts and subsystems, as well as to stimulate cross-company business networking. The project was carried out through collaboration between an automotive manufacturer, 35 automotive suppliers, and six universities, most with Swedish affiliation. The initial phase of the project was devoted to a creative concept study. For this purpose, a research team selected and facilitated systematic design methods for requirements setting, creation, and evaluation of product concepts. Through a workshop-based approach, 63 individuals organised in eight sub-teams set out on developing innovative product concepts using the methods. This paper describes these methods as well as demonstrates their application.

Keywords: Collaborative design, Conceptual design, Design methodology, Innovation, Sustainability

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1 INTRODUCTION

Generally, automotive industry is highly advanced from the point of view of incremental innovation, cost efficiency, and quality assurance. However, facing the challenges from current environmental requirements, there is a need for more radical innovation. In addition, in the current structure of the automotive industry, OEMs are entrusting the first tier suppliers' innovation capability. However, in particular large and global first tier suppliers are prone to protect current investments leading to reluctance to radical changes. At the same time, small and medium-sized second and third tier suppliers offer new technologies regarding materials and production approaches. Thus, there is great potential in utilising these companies for developing new concepts and solutions. However, in order to pave the way for this, one has to provide an approach for collaborative development of radical innovations.

Such approaches were applied in a research project (SÅNÄTT, 2013) aiming to develop resource-economic and lightweight car concepts and subsystems, as well as to stimulate cross-company business networking. The project was carried out through collaboration between an automotive manufacturer, 35 automotive suppliers, and six universities, most with Swedish affiliation. In line with the ambition to support more radical innovation, a key enabler for the project was to exploit process knowledge and methods already available in academia. The initial phase of the project was devoted to a creative concept study. For this purpose, a research team selected and facilitated systematic design methods for requirements setting, creation, and evaluation of product concepts. Through a workshop-based approach, 63 individuals organised in eight sub-teams set out on developing innovative product concepts using the methods. These methods as well as their applicability are presented and discussed here.

More specifically, the challenges and opportunities presented above lead us to the following research questions:

- Are the applied methods appropriate?
  - How do they support a shift towards radical innovation?
  - How do they support collaborative development?
- How applicable are the methods in the teams?

2 RESEARCH APPROACH

Reflecting the scope of a multidisciplinary project, the research strategy takes its point of departure in a qualitative systems approach and a case study methodology. In addition, in order to meet the ambition to advance in terms of both technology and work practices, an action-based research approach (e.g. Hult and Lennung, 1980; Ottosson, 1996; Westlander, 1999) was deployed. The key decisions (cf. Chisholm and Elden, 1993) of the action research process were made by the involved researchers, who had many years' experience of both industrial development work and research in academia. Specifically, they selected approaches assessed well-suited for the problem situation at hand, while addressing the project's challenging targets and having in mind the overall notion to utilise existing knowledge of the different partners (industrial as well as academic). The approaches were implemented through a three-step workshop series with duration of about four months. The full manning was organised in eight sub-teams that applied, essentially, a common approach for concept development, while each team was responsible for a particular system area. The teams' work and output were documented and followed-up using multiple information sources (cf. Yin, 1994), including PowerPoint presentations, photographs, logbook notes, and a follow-up survey (answered by 25 individuals). Findings were analysed mainly across the eight teams but also regarding the project's process and progress in full. Specifically, the approaches' general acceptance among experienced engineers was explored (cf. Buur, 1990), while also considering their support for thinking "outside the box".

Adopting the action-based research approach described above, the following types of results can be expected:

- Problem-solving; process output in terms of new or improved technology and product concepts.
- Research; findings on design methodology in theory and practice, in particular its applicability in cross-disciplinary innovation work.

- Learning; enhanced tool box for problem problem-solving at individual level, and enhanced ability to work as an innovation team.

3 OPPORTUNITIES AND CHALLENGES IN CROSS-DISCIPLINARY INNOVATION

While generally being driven by the potential of utilising the knowledge of involved suppliers and universities, the project also had to take particular opportunities and challenges into consideration. These include perspectives on technology, industrial structure, and work procedures.

3.1 Technology

Automotive industry is among the leading when it comes to incremental development and quality assurance. At the same time, development culture within both OEMs and suppliers is characterised by a component mind-set. For instance, when targeting weight reductions one is prone to propose material changes for particular components rather than changing principles at system level. However, it is reasonable to assume that there is a great opportunity in adopting more systems thinking in order to reduce system complexity and weight. Specifically, there is potential in utilising synergies between different solution principles as a means for reducing weight without sacrificing other product attributes.

3.2 Industrial structure

The industrial structure of automotive industry, both OEMs and suppliers, can be considered as institutionalised. Typically, the companies have a line organization reflecting the product structure and a project organization for carrying out the development projects. A common perspective is that respective line function provides a component responsible to the project, and thus contributes in manning a cross-functional project team. Indeed, such a set-up supports sharing of expertise knowledge. In this research project, however, we wanted take this notion further, and let the project members take more system responsibility and be allowed to co-create all constituents of the system. Thus doing, the product structure may also be changed.

3.3 Work procedures and team dynamics

Both methodology and team dynamics were considered to address the ambition to support multi-disciplinary collaborative work and a shift towards more radical innovation. A particular challenge was to make experienced experts practically and mentally prepared to solve open problems. Here systematic design methodology was thought to serve as a shared arena for taking care of all team members' ideas and knowledge. In addition, realising that development work is also a social-cultural process, the work sessions were supported by a social psychologist.

4 METHODOLOGICAL APPROACH FOR PRODUCT INNOVATION

This section outlines the methodological principles, individual methods and practical arrangements underlying the reported project phase and its workshop series, while reflecting the opportunities and challenges described in Section 3.

4.1 General points of departure

An innovation process inherently involves dynamics, uncertainty, fuzziness, and assumptions. While keeping awareness of that, the researchers wanted to provide a clear, comfortable, and encouraging arena for the involved parties and individuals. Reflecting this, the researchers introduced a structured work process with roots in systematic design (cf. e.g. Pahl and Beitz, 1996; Ulrich and Eppinger, 2012); formalised but not formalistic, with common work procedure and time plan but high tolerance regarding norms and solutions. Thus, a key notion was to convey security through the methodology, rather than through certainty about targets and output. Along with this, a notion was to provide a shared arena in which all individuals could be actively involved and equally collaborate. The aspect of team dynamics was also considered, and supported by a social psychologist. Thus, the teams were given mandate to see and reflect on conflicts and difficult situations.

4.2 The innovation process

Basically, the innovation process adopted in the reported concept study is similar to a typical systematic design process, thus proceeding from abstract to concrete and being driven by some kind of problem statement. The actual process was divided into three main activities, and the implementation was motorised through a workshop series. During the concept study, in total 15 workshops were carried out, and each of the eight sub-teams was involved in four. In between workshops the teams had additional activities to document, organise and review their productions. Figure 1 provides an overview of the process and workshop series, as experienced by each sub-team.

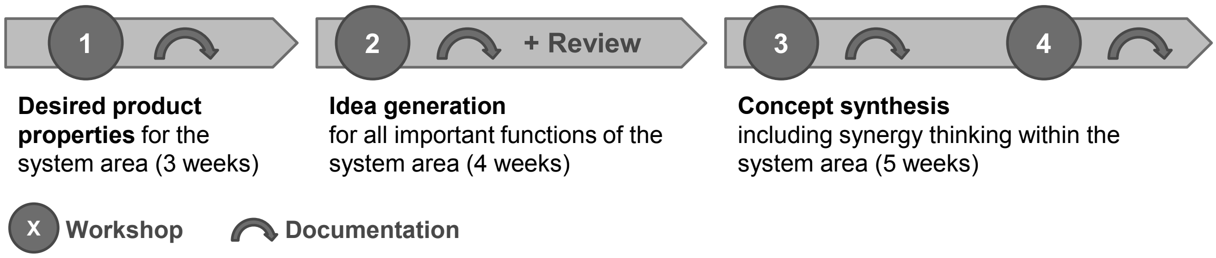

Figure 1. The innovation process as implemented in each team

Along with the process in Figure 1, the following approaches were adopted and introduced to the teams:

- Definition of desired product properties and functionality *before* suggestion of solution principles, while having the intention to stimulate the search for new, innovative solution principles.
- Encouragement to propose many alternative solutions for a certain function or system area (cf. “Set-based concurrent engineering”, e.g. Sobek et al., 1999; Raudberget, 2011), while having the intention to stimulate a creative atmosphere as well as to increase the opportunities for synergetic combinations with adjacent components or system areas.
- Concept synthesis characterised by systems thinking, in particular consideration of synergies between different sub-solutions (cf. Almefelt, 2005), meaning that the sub-solutions match particularly well and result in an effective overall solution.
- Functional sharing, meaning that a particular component implements several functions, or that several components are replaced by a single one.

Generally, the purpose of the process was to stimulate a shift from engineering to more radical innovation, while having weight reduction in mind. The targeted output as communicated to the teams was “A multitude of ideas and approximately three concepts per system area”.

4.3 The team set-up and roles during the concept phase and its workshop series

The arrangement of teams and workshop series was supported by experiences from a previous co-creation study (Rexfelt et al., 2011). Here, the participants of the project were clustered in eight sub-teams with about ten members each, and with responsibility for a particular system area of a car, e.g. “seats”, “wheel suspension”, and “complete vehicle”. The manning of each team was multi-disciplinary reflecting the notion that “creativity is stimulated when individuals from different contexts meet”, as well as to assure presence of complete knowledge. Thus, each sub-team comprised members from the OEM, suppliers and academia, see Figure 2. One of the team members was appointed as team leader and one as sketching support. In addition, during the workshops the teamwork was supported by a facilitator (one of the researchers), having method knowledge but aimed to be politically unbiased. In summary, the guiding mind-sets behind the teamwork were:

- Teams with complementary competences.
- Trust between parties.
- Collaboration across borders.
- Respect for the individual’s competence.
- Encouragement to take risks, reflect and think out-of-the-box.
- Environment outside ordinary operations.
- Welcoming attitude, common coffee breaks and lunches.

As seen in the list, the physical setting was considered along with the team set-up. One of the involved universities served as host for the actual workshops, thus providing a secluded environment separated from most parties' ordinary operations. It was also reasonably accessible for all involved.

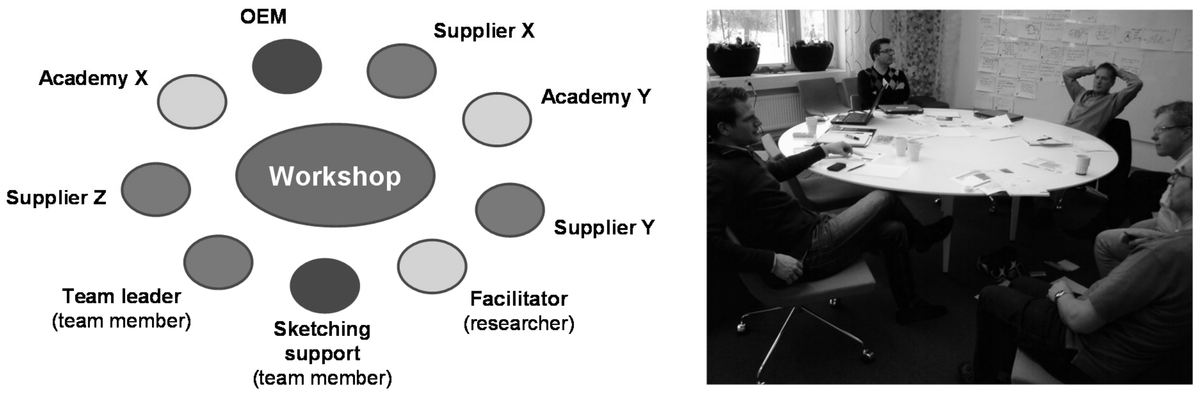

Figure 2. Cross-disciplinary teams with complementary competences

4.4 Methods selected for the individual workshops

The methods were essentially selected to address each main activity of the process of the concept study, i.e. definition of desired product properties, idea generation for important functions of a system area, and concept synthesis. Particular influence was taken from previous research on synthesis with simultaneous consideration of synergies between sub-solutions with reference to product properties (Almefelt, 2005).

4.4.1 Method for definition of desired product properties

Each sub-team elaborated and formulated desired product properties for their own system area. The resulting desires were then prioritised and represented through a bar diagram, a "desired performance profile" (Almefelt, 2005), see Figure 3. Thus, the bar diagram captures the intent for the envisaged product. The length of the bars corresponds to the targeted performance level, and their thickness to the property's relative weight in its system context. For each property, a minimum acceptable performance is set in order to avoid unsatisfactory performance of individual properties. The grade scale (0 – 10), is user value-oriented, and derived from value scales according to VDI 2225 (e.g. Pahl and Beitz, 1996) and standard scales in Swedish automotive industry.

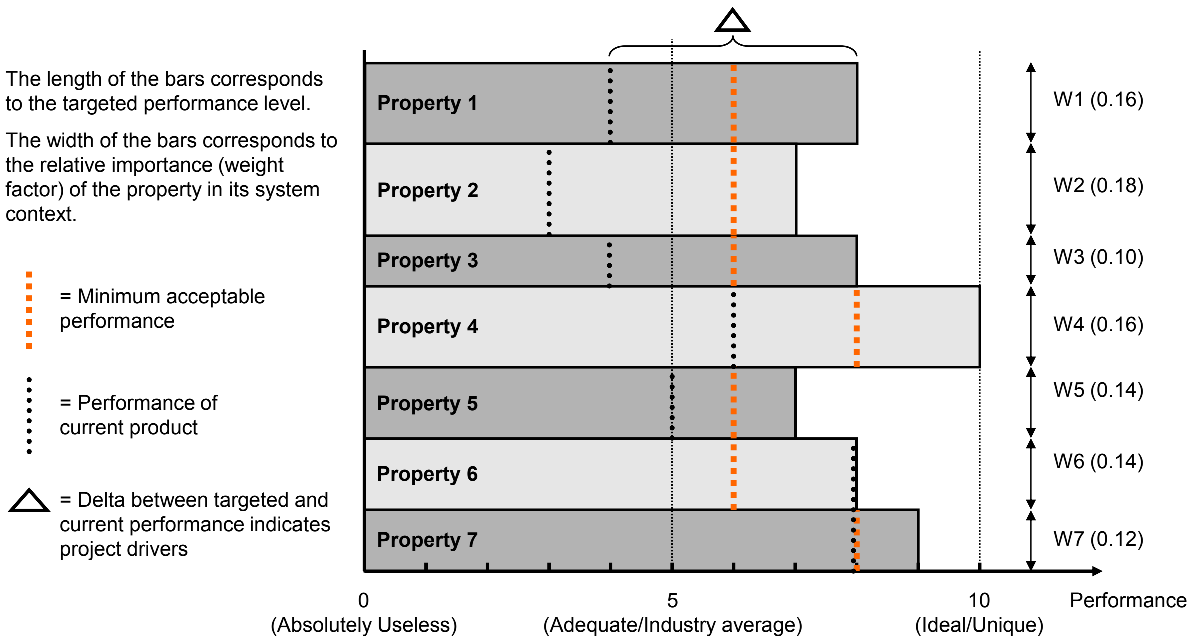

Figure 3. Desired performance profile used to capture the intent of a product system

4.4.2 Method for idea generation

In each sub-team, the idea generation activity addressed envisioned functions of the system area. A morphological matrix (Zwicky, 1971) was used as method support. The actual idea generation workshop started off with definition of the system area's most important functions, based on a tentative list that the team leader had compiled in advance. A wide range of alternative solution proposals were then generated for each function. After the workshop, the ideas were reviewed in the team, sketched in a universal format and re-organised in the morphological matrix.

4.4.3 Method for concept synthesis

Since concept synthesis is both challenging and time-consuming, two workshops were devoted to this matter. With the filled-out morphological matrix as basis, each sub-team was given the task to synthesise between two and three alternative system concepts, and address a range from "next generation product" to "visionary". The teams were encouraged to continuously have the "desired performance profile" at hand. In addition, while synthesising concept proposals they were encouraged to consider synergies between sub-solutions, and were also provided with a formalised sheet for that purpose. Thus, the concept synthesis activity involved both creation and evaluation. After the workshops each concept proposal was compiled through a concept sketch with key principles and their effects, design rationale, or value highlighted.

5 THE APPLICATION IN THE TEAMS: FINDINGS AND DISCUSSION

In Section 4, a methodology for innovation was described and justified, along with a set-up for its application. Next follow results of the proposition in action. The findings presented are based on analysis of the teams' productions, along with our own documentation of the case. Specific information sources include PowerPoint presentations, photographs, logbook notes, and a follow-up survey (as mentioned in Section 2).

5.1 General observations and reflections

Generally, the application of the methodology was successful, in particular in the sense that all teams were very productive. In the beginning of the workshop series, however, some teams struggled to get up to speed. A possible reason for this phenomenon is the fact that it takes some time to get used to the philosophical mind-sets and terminology of the applied systematic design methods. In addition, in some of the teams the work progress was seemingly hindered by conflicts of interest. This phenomenon was observed in particular in teams where the parties represented competing solutions, e.g. regarding material technology. Nevertheless, from a holistic perspective, there were no major differences regarding the amount of output from the teams. The format for representing the output was also very consistent between the teams. Thus, communication between the teams was supported. In addition, it suggests the general applicability and repeatability of the methodology.

While the application of the methodology showed a consistent pattern, the solution space was certainly diversified. Some individual solutions were also very innovative, e.g. in the sense that they solved property conflicts that traditionally have existed in a certain system area. Consider, for example, the wheel suspension team that proposed a concept with influences from motorbikes to avoid bending moment and in turn reduce weight.

With a few exceptions, the team spirit was also great and remained so throughout the subsequent phases of the research project (another two years not reported in this paper). This aspect is also important, since one of the central aims of the project was to stimulate cross-company business networking. Reflecting this aim, it is worth noting that the question "Will you continue working with one or more (that you didn't work with before) of the partners from the project?" was answered "Yes" by 17 of 25 survey respondents and "No" by only 2.

5.2 Findings from the application of individual methods

Below some key findings from the application of the individual methods for the main activities of the innovation process (see Figure 1) are presented. Along with this, examples of the teams' output are shown in order to further demonstrate the application and provide transparency into the study.

5.2.1 Findings from the activity of definition of desired product properties

All teams were successful in using the format “desired performance profile” for defining the intent for the envisioned development of their respective system area, see four examples in Figure 4. The work was also characterised by discussions about values and norms with reference to their particular system area as well as cars in general. Thus, the teams questioned today’s standards regarding functionality and performance, for instance whether it is really necessary to be able to lower and elevate windows, or the necessity of being able to drive more than 160km/h. Nevertheless, the teams also identified the need for raising requirements on some properties; weight of course, but also e.g. thermal insulation.

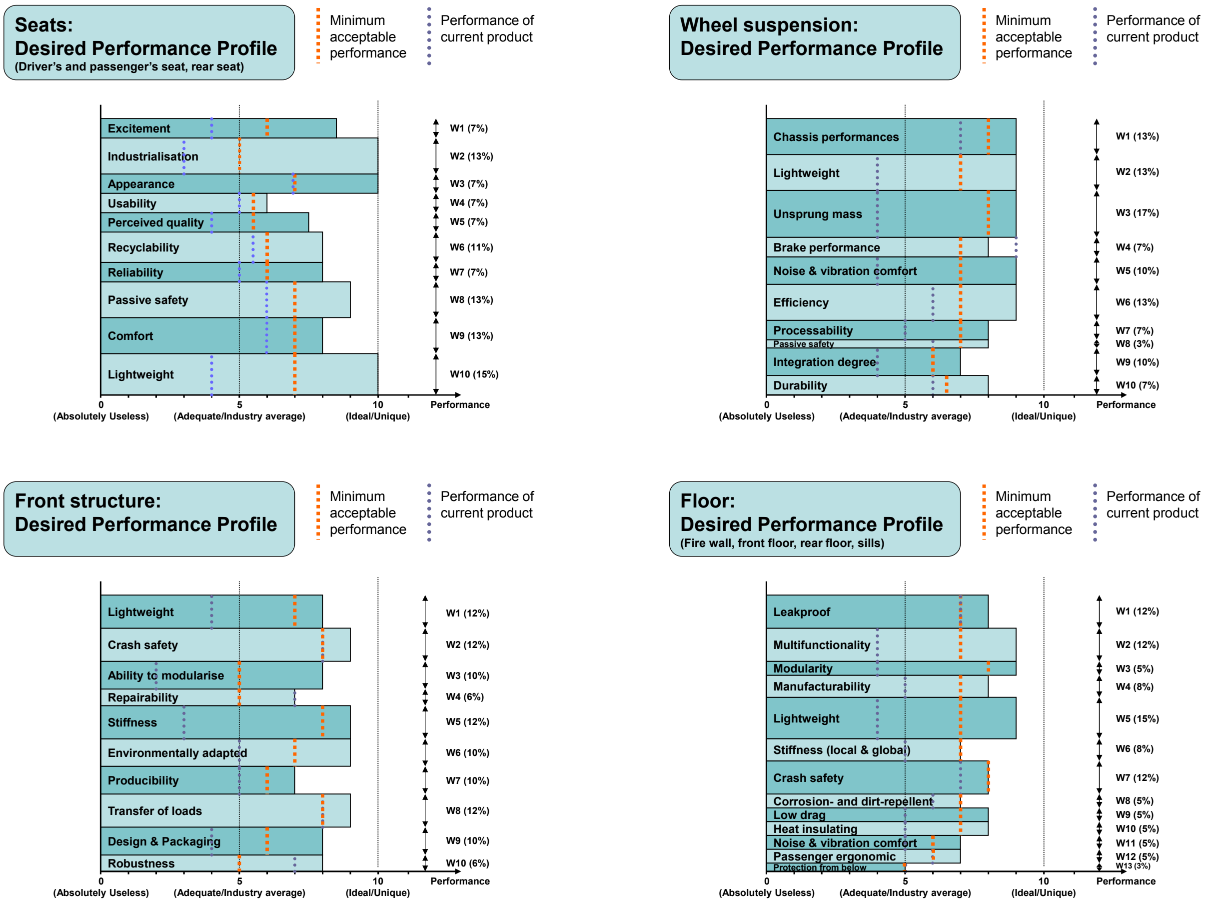

Figure 4. Examples of desired performance profile (from four teams)

5.2.2 Findings from the idea generation activity

The idea generation activity using the morphological matrix was both productive and characterised by a great team spirit. Figure 5 exemplifies this, by showing a part of the morphological matrix as elaborated by the wheel suspension team. Based on the follow-up survey after the full project, the morphological matrix also appears to be the individual method that the project participants are most willing to use in future: As the 25 survey respondents freely answered the question “Will your company utilize any of the processes from the project within your company?” the most common answers relate to systematic design and the morphological matrix in particular (cf. “Verification by acceptance”, Buur, 1990).

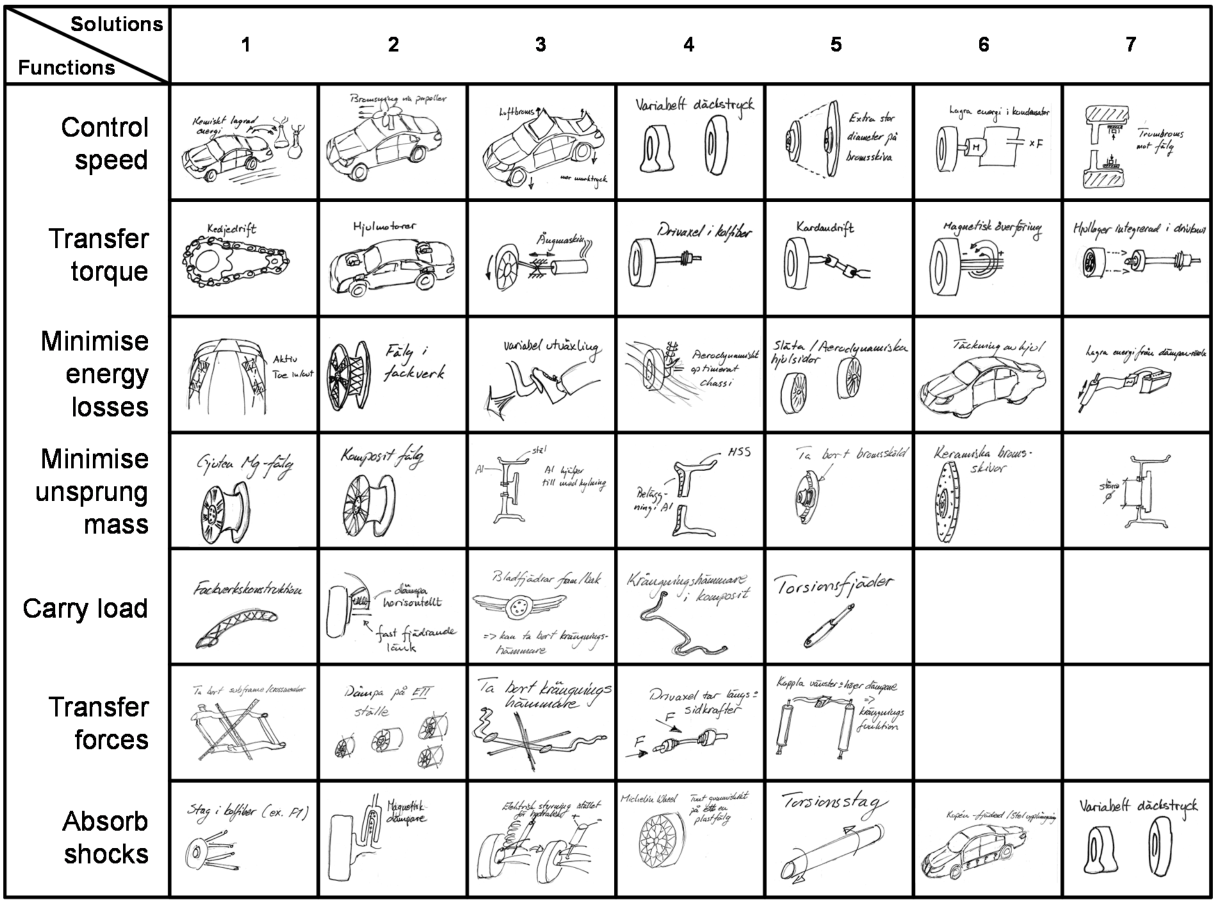

Figure 5. Morphological matrix as applied in the wheel suspension team

5.2.3 *Findings from the concept synthesis*

With respective morphological matrices as bases, all teams were successful in generating concepts. Thus, six of the teams produced three concept proposals each, and two of the teams even produced four. Generally, the teams actively addressed desired product properties and considered synergies between sub-solutions in line with the ambition to increase functional integration. Many teams, though, did not fully apply the sheets for formalised synergy analysis. Thus, the proposed format was seemingly not enough easy to understand and apply, which is an essential aspect of applicability (cf. Norell, 1992). Moreover, some teams produced more radical concepts than others. Comparing the resulting concepts from the teams, it is worth noting that the teams with the less radical solutions were those where the parties had apparent conflicts of interests. Anyway, all in all the teams produced concepts that addressed central properties and functions. All teams were also successful in representing their concepts, using sketches with key principles and their effects, design rationales and values highlighted, see example in Figure 6.

5.3 Particular surprises and insights

As reported in the previous sub-sections, the applied approach was found appropriate to support both innovation and collaboration. Nevertheless, findings also include aspects not foreseen in the research plan. For instance; cross-company co-creation was indeed supported, but in a couple of teams the progress was seemingly hindered by conflicts of interest. Possibly – as stated by one of the individuals from industry – one should avoid putting competing suppliers in the same sub-team. At the other end of the scale we find collaboration resulting in joint patent claims and continued cross-company development work. In this particular case, the key parties are one large component supplier and one large consulting firm. Reflecting this example, a respondent of the follow-up survey puts forward that there should have been an IPR-budget in the project plan. Generally, though, it's reasonable to assume that collaboration across borders is better supported by providing full transparency and common access to all results. Thus, one should also consider the strategy of making results public, and explicitly communicate this to all involved.

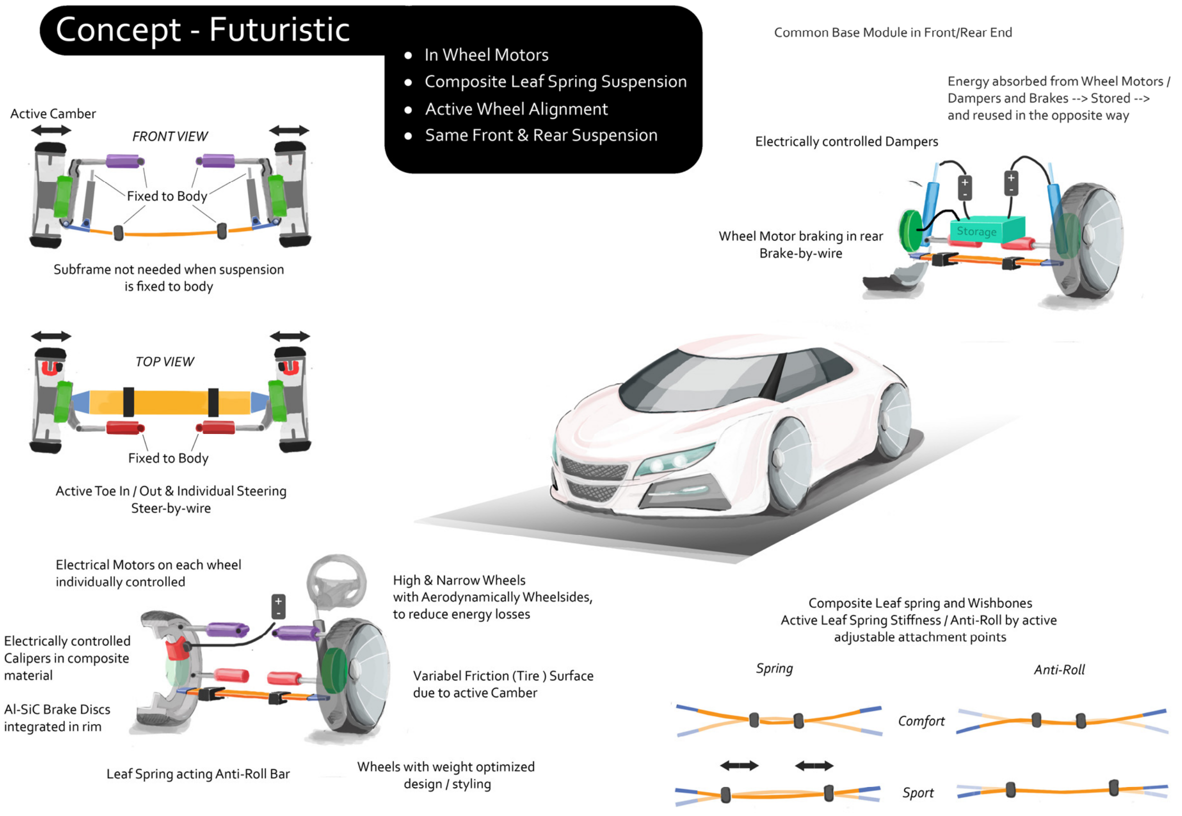

Figure 6. Example of a concept proposal and its representation (wheel suspension team)

6 CONCLUSIONS AND FUTURE WORK

While referring to the project aims and research questions presented in Section 1, one can conclude that the concept study and its method applications supported active multi-disciplinary collaboration and networking as well as outputted many innovative product concepts with potential for weight savings. Specifically, the notion of defining desired product properties and functionality before suggesting solutions opened up the solution space and paved the way for innovative product concepts. In addition, the methods and the set-up for their application provided an arena where all parties were enabled to both collaborate and contribute with their own ideas and expertise. The practical applicability of the methodology was also demonstrated, supported by the fact that all teams were successful in producing the targeted output within schedule. In many cases, though, it took time for the individuals to become familiar with introduced notions and terminology. Finally, regarding learning effects on the individual team members, it is reasonable to assume that many have taken a leap forward regarding the ability explore the unknown and propose what yet not exists.
Future work should consider:

- The concept study reported in this paper was a limited part of a two and a half years' project. While some end results of the full project have been touched upon, there is more to report on. In particular, future research could explore lasting effects of the concept study, e.g. regarding how mind-sets, aims and solutions were maintained and evolved over time in the full project.
- Consideration of synergies between different solution elements was found to be an appropriate mind-set for increasing system thinking and level of integration. Still there is a need to elaborate a more intuitive and easy-to-apply formalised approach for that.

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