Decision Methodology for Planning Product-Service Systems

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Abstract

One challenge for product development is the change from solely tangible products to more immaterial goods, such as services. This requires offering more than just a product, but opens new business models on the other side. This deferral is called the product-to-service-shift. Combining products and services to a product-service system (PSS) enable companies to better meet customers' requirements or to increase customer connectivity and to focus on own core competencies. Since PSS are more complex and more interrelated than stand-alone products, developing PSS requires different methods and frameworks. The planning phase for PSS is relevant for the market success, as most important decisions are made in early stages of product development. For this reason, planning PSS requires special methodical support to enable reliable decisions. In this paper, we built a decision methodology for PSS-planning by combining a process model with several methods from previous works. To evaluate its applicability, we conducted a case study from industrial practice and used the methodology for the planning phase of vehicles. The product's complexity and organizational requirements were high enough for needing methodological support. The case study reveals the need for the methodology and its benefits in a real application.

Keywords: product-service systems, decision-making, product planning, process framework, uncertainties

1. Introduction

During the last decades, market offers shifted from solely tangible products to a combination of both tangible products and immaterial services (Wimmer et al., 2008). This combined market offer is a well-promising approach to better meet customer needs (Mont, 2002), to increase products' sustainability (Mont, 2004), to strengthen the customer locality (Mont, 2002) or to focus on own core competencies (Schenkl, 2014). Researchers (Schenkl, Behncke, Hepperle, Langer, & Lindemann, 2013a; Tukker, 2004) declare this kind of integrating offer as a product-service system (PSS). The nature of PSS implies that the integrated product part and service parts cannot exist without each other and just the combination of both makes the PSS to a beneficial market offer. The strong interconnection of product and service causes a change in the requirements for designing PSS compared to designing only tangible products: companies have to consider interactions and interfaces between product and services from the very beginning of the design process and other innovation processes. Unlike the conventional design process of tangible products, the company's service department cannot start to develop the service after designing the tangible product. PSS-design requires the integration of the service department into the early stages of product development. Since developing PSS differs from developing stand-alone physical products or services, the PSS-planning process has to be adjusted to the PSS-specific requirements for a planning process. A PSS-planning process has to consider tangible components, service components, the merging infrastructure, the company's knowledge and competencies, and external factors (Schenkl, Spörl, Behncke, Orawski, & Mörtl, 2013c). For planning and developing PSS, they have to orient to the customers and their needs. This makes it necessary to raise the level of customer integration in the early phases of PSS-development, compared to the level of customer integration the developing stand-alone physical products or services.

The product development and so is the PSS-development (Jupp, Eckert, & Clarkson, 2009) requires many decisions (Krishnan & Ulrich, 2001): Designers have to decide about product design, components, services, technologies, materials and innovations. During product planning, the price, core product concept or product architecture have to be determined (Krishnan & Ulrich, 2001). The core product concept contains decisions about product's sub-systems or sub-sub-systems, which influence product's parameters. The early stages of PSS-development give direction to the market success of PSS, because those stages define issues most relevant for customer acceptance (Schmidt, Bauer, & Mörtl, 2014a; Schmidt, Malaschewski, Fluhr, & Mörtl, 2015a; Schmidt, Malaschewski, & Mörtl, 2015b). While decisions in early stages of product development are essential for market success, extreme uncertainties complicate decisions in early phases of product development. To handle decisions in early phases, methodical support is necessary to facilitate equitable decisions and a consideration of all relevant factors. Suitable methods, models and tools must include the characteristics of PSS to fulfill the requirements on planning and developing PSS (Jupp et al., 2009).

2. State of Research

In previous works, we conducted literature researches about decision making for the planning phase of PSS (Hepperle, 2013; Herzberger, Behncke, Schenkl, & Lindemann, 2013; Kammerl, Bauer, & Mörtl, 2014a; Kammerl, Enseleit, Orawski, Schmidt, & Mörtl, 2014b; Kammerl, Malaschewski, Schenkl, & Mörtl, 2015; Orawski, Hepperle, Mörtl, & Lindemann, 2010a; Orawski, Hepperle, Mörtl, & Lindemann, 2010b; Orawski, Krollmann, Mörtl, & Lindemann, 2011; Schenkl, 2014; Schenkl et al., 2013a; Schenkl, Rösch, & Mörtl, 2014a; Schenkl, Sauer, & Mörtl, 2014b; Schenkl et al., 2013b; Schenkl et al., 2013c; Schmidt et al., 2014a; Schmidt et al., 2015a; Schmidt et al., 2015b; Schmidt, Schenkl, & Mörtl, 2014b). Schmidt et al. (2015b) analyzed existing processual frameworks and methodologies for planning PSS (Aurich, Fuchs, & Wagenknecht, 2006; Gausemeier, Fink, & Schlake, 1996; Geum & Park, 2011; Maussang, Sakao, Zwolonski, & Brissaud, 2007; Morelli, 2002; Orawski et al., 2011; Tonelli, Taticchi, & Starnini, 2009; van de Kar, 2008; VDI, 1980; Yang, Xing, & Lee, 2013). While most of them considered a market analysis and the coexistence of services and product components, just a few approaches (Aurich et al., 2006; Geum & Park, 2011; Tonelli et al., 2009; van de Kar, 2008) provide a sufficient customer integration, which is essential for planning PSS. PSS are suitable for customer-focused product offers and customization (Schenkl et al., 2013a), which also have to be regarded in the planning phase. Only three approaches (Orawski et al., 2011; VDI, 1980; Yang et al., 2013) considered an iterative evaluation of concept ideas. As the planning phase in industrial practice is characterized by several iterations, a suitable process framework has to be able for iterations. For those and other reasons described in Schmidt et al., we have developed a process framework for planning PSS (Schmidt et al., 2015b). This Framework fulfills the requirements of customer integrations, adaptable requirements list, planning PSS-infrastructure or consideration of strategy and is for those and other requirements more beneficial and more applicable compared to other approaches from literature.

2.1 Previous Work

As we need more than just a process framework to build a decision methodology, we have developed several methods which support the planning phase and which can be integrated in the process framework. Schenkl et al. (2013c) identified relevant decision criteria from literature, which are usable for planning PSS. To support decisions in PSS-planning, they developed a block model for weighting the criteria for cyclical decisions. It is based on the pairwise comparison according to Breiing and Knosala (1997) and it weights the criteria to each other and the decisions' relevance to each other. To handle uncertainties during planning PSS, Kammerl et al. (2015) developed a method to determine uncertainties of PSS-elements concerning the decision criteria. For this, they identified factors relevant for uncertainties and provided a method for assessing the PSS-elements and the decision criteria concerning those factors. Overlying those assessments of PSS-elements and criteria concerning the uncertainty-factors results in the relations, which represents the uncertainty that a PSS-element will success concerning a decision criterion. For analyzing the compatibility of PSS-elements to each other, we have developed a matrix-based compatibility analysis (Schmidt et al., 2014b). This is relevant for combining PSS-elements to a PSS-concept, because beyond the fulfillment of the decision criteria is relevant for selecting PSS-elements, but also how the PSS-elements fit to each other. For this, we adapted the structure-based compatibility analysis according to Hepperle (2013). In previous work, we developed a methodical deployment of quality criteria to assess quality-relevant product properties (Schenkl et al., 2013b). This method supports to evaluate the PSS-concept in comparison to competitive products and to reach a cost-efficient level of quality. It compares the quality perceived by customer or user to the needed costs.

Except for the methodical and processual support of the decisions, we provided a PSS-model, which represents the decision object and serves as a way to visualize and organize the PSS-relevant data which appear in the planning process. Kammerl et al. (2014b) developed based on Schenkl et al. (2014b) a PSS-model which involves product components, service elements and connecting infrastructure. Product components are tangible product elements or product innovations, which can be seen on the three layers function, behavior and structure. Those elements can be fixed or mandatory for the PSS or they can be optional and organized in different variants. Services and its elements can be seen on the layers function, process and resource. Schenkl et al. (2014b) describes the connecting infrastructure as the link between product and services, like the communication structure of a PSS. This PSS-model visualizes more than just a PSS-concept it also can visualize a PSS-portfolio. Such a portfolio includes all possible PSS-elements, which can be product, service elements or parts of the connecting infrastructure. To face the flexible character of innovation processes, the PSS-model is flexibly adaptable (Orawski et al., 2010b). To provide this flexibility and to integrate the whole PSS-lifecycle (Hepperle, 2013) over several product generations, PSS-portfolios depicting different product generations are to be synchronized to each other (Orawski et al., 2010a). This facilitates the strategic components integration into the PSS-portfolio: If a product innovation consistent of several product components is mandatory in 20 years, some of the needed components might be integrated in today's PSS-portfolio to simplify the implementation of the whole product innovation. PSS-portfolios consider the temporal background. This can be used to plan and integrate product technologies over time.

2.2 Research Clarification

Other approaches lack in customer integration or in providing adaptable requirements, as described before. Furthermore, they only focus the processes or the knowledge organization but they do not provide a broader methodical support for planning PSS or the integration of PSS-models. Existing approaches focus either the methodical, the processual or the modelling part of planning PSS. Our research will combine several methods, the PSS-model and the process framework for planning PSS to a continuous decision methodology. This combination reveals relations between methods and the benefit of PSS-models. Furthermore, just a few existing approaches were applied and evaluated in an industrial case study. To examine the advantages, disadvantages and applicability of our methodology, we will apply it in a real case study in automotive industries.

After this literature study, we will present our decision methodology in the next chapter. In chapter 4, this methodology will be applied in a case study and the results of the case study will be presented. Chapter 5 deals with the findings of the case study and concludes the entire work.

3. Decision Methodology for Planning Product-Service Systems

In order to meet the challenges for planning product-service systems, described in the introduction, we developed a decision methodology for early stages of product development. In preliminary work, we developed a processual framework for product planning (Schmidt et al., 2015b) and in this paper, we expanded the framework by methods and tools to a complete decision methodology. The overall methodology is shown in figure 1 and ranges from the definition of product ideas to the ensured product concept, which is seen as the final stage of the early phases of product development. The first step of our approach is the definition of requirements and decision criteria, which will be used for all decisions in product planning. Step 2 acquires the elements of the PSS (e.g. tangible components, service components). The next step investigates the interrelations and correlations between PSS-elements. After that, the uncertainties expected for the planning and development process are determined. In step 5, the overall product concept is built. The last step of our methodology ensures the product's quality.

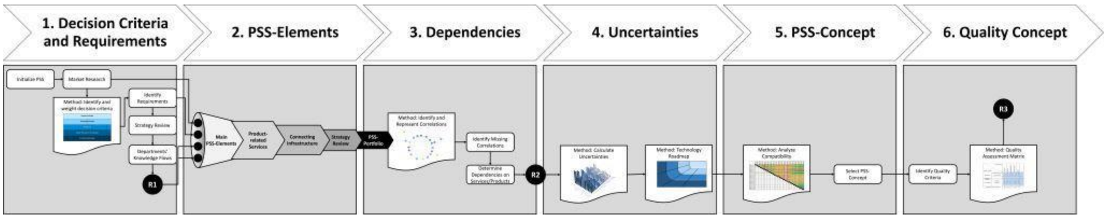

Figure 1: Overview Decision Methodology

The steps of our methodology are explained in the next subsections and we provide methods used for the described steps.

3.1 Step 1: Decision Criteria and Requirements

This step starts with the definition of a product idea (initialize PSS) and a following market research. Based on the results of the market research, relevant decision criteria are defined and weighted. For this, we used the decision criteria defined by Schenkl, Spörl, Behncke, Orawski, and Mörtl (2013c), which is a generic collection of decision criteria for PSS-planning gathered in a literature research. The block model (Schenkl et al., 2013c) provides a method for determining the importance and relevance of decision criteria. This weighting quantifies the scale the decisions should consider the criteria. This weighting must fit to the product and corporate strategy, this matching is also done in this first step. Furthermore, a first set of requirements is collected, based on the decision criteria. The weighting of the decision criteria can also serve as an estimation of development effort, as the decision criteria can be seen as sources or categories for requirements (Schenkl et al., 2013c). This estimation of development effort is a decision support for the budget allocation. Furthermore, an interdisciplinary workshop is conducted, where people from all attending departments discuss the requirements and evolve the information flow between the departments. This enables an efficient knowledge transfer between departments and integrates all departments in all stages of the design process. This first step ends with the R1-Review of our decision framework (Schmidt et al., 2015b), which describes the decision about the requirements.

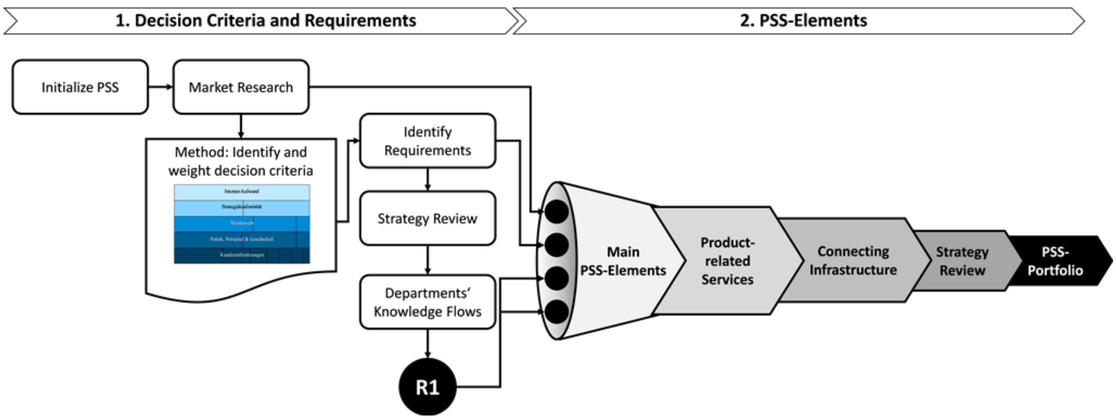

Figure 2: Stages and Methods of Step 1 (Decision Criteria and Requirements) and Step 2 (PSS-Elements)

3.2 Step 2: PSS-Elements

In this step, the service elements, the product components and the elements of the connecting infrastructure (Schenkl et al., 2014b) are identified. Based on requirements from market research, customers, previous products or technologies, the business model and main product elements are identified. Those main product elements can be tangible product elements or services. This depends on the selected business model. Afterwards, additional services for the PSS-offer are identified. The connecting PSS-infrastructure is conceptualized and the elements are adjusted to future scenarios. The result is a basic range of elements which are possible solution elements for the final PSS-concept. This is a PSS-portfolio of all possible elements which might be combined to one PSS-offer (Kammerl et al., 2014b).

3.3 Step 3: Dependencies

This step investigates the dependencies between requirements, functions, product components and service components. Linking these elements builds the PSS-architecture and analyzing this architecture reveals modules for the development process. Those modules are elements with a high degree on connectivity to each other and consists of both tangible product components and service elements. The module design requires inter-departmental cooperation and a clear interface definition. Studying interrelations between modules facilitates the identification of interface elements and the departments, which the interface is relevant for. To improve the consistency of the concepts, missing relations must be identified and considered. As the PSS-architecture depicts the relations between product components and service elements, the dependencies between them can be determined. This step ends with the R2-review (Schmidt et al., 2015b). This review ensures that PSS-elements cover all defined requirements and that the PSS-portfolio is completed (Orawski et al., 2010a).

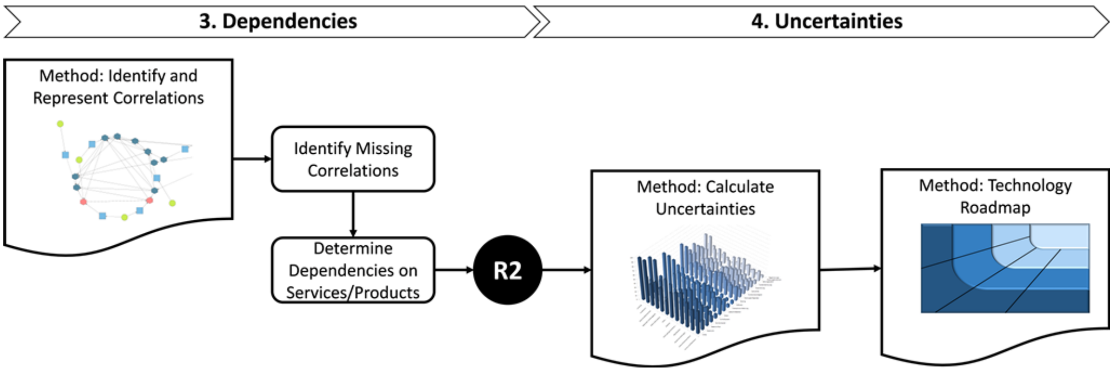

Figure 3: Stages and Methods of Step 3 (Dependencies) and Step 4 (Uncertainties)

3.4 Step 4: Uncertainties

In step 4, the uncertainties of elements and components regarding the decision criteria are calculated and measures to handle uncertainty are identified. We calculate the uncertainties of product components, service elements and product innovations, which consist of a combination of product components and service elements. For this calculation, we have developed a method which considers indirect relations between the PSS elements and the decision criteria and determines their uncertainties (Kammerl et al., 2015). Considering the innovations' and elements' uncertainties and the relation between the uncertainties and the time, defines the maturity of innovations dependent on the time. A technology roadmap depicts the time-dependency of innovations (Kammerl et al., 2014a).

3.5 Step 5: PSS-Concept

The step "PSS-Concept" describes the selection of PSS-elements, identified in step 2, and a combination of them to a coherent PSS-Concept. This can happen by an evaluation of the components and partial concepts regarding the decision criteria. This concept might be checked for the compatibility between components. For this, we developed a compatibility analysis (Schmidt et al., 2014b).

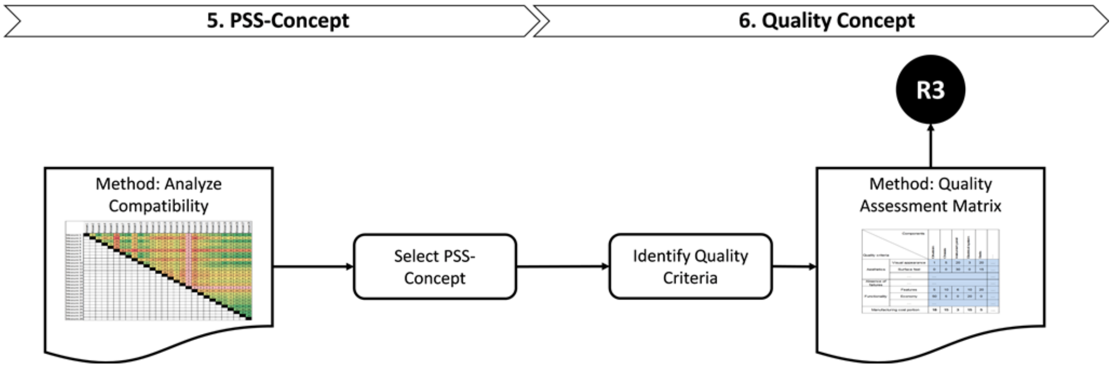

Figure 4: Stages and Methods of Step 5 (PSS-Concept) and Step 6 (Quality Concept)

3.6 Step 6: Quality Concept

To construct the quality concept, relevant quality criteria, like features or ergonomics, are identified. The concept and competitive products are compared concerning the quality criteria (Schenkl et al., 2013b). Products are evaluated in three stages: AS (Accepted Standard), TOP (Top three of market), BID (best in dimension). This reveals the unique selling points for the concept and the quality assessment matrix compares the components production costs to the decision criteria. This matrix justifies the components production costs and might identify components with too high production costs compared to the components' benefits.

4. Case Study: Evaluating the Methodology

To evaluate our methodology and the methods and tools, we applied them at the planning phase of a vehicle, while we focused the driver's cab. The vehicle should be in production line status in 5 years. This case study involves the identification and planning of new product components and new services. In the following, we describe the application of our methodology. The product components and services are relevant elements of the planning process for this case study. In the case study, we neglected the connecting infrastructure as an own domain and modeled elements of the infrastructure as product components. The connecting infrastructure of the regarded vehicle is relevant for the concretization of the development process, but it is of less importance for the planning process.

4.1 Step 1: Decision Criteria and Requirements

As described before, the focused product is a vehicle. The marketing department conducted the market research. After that, the product management applied the method for identifying and weighting the decision criteria (Schenkl et al., 2013c). They identified the criteria shown in figure 5, which are closely related to the requirements. The categories defined by Schenkl (2013c) were sufficient for our case; every criterion was allocated to a category. The categories cover all relevant criteria and help the product management to identify decision criteria. Even though we cannot proof if all relevant criteria were identified, we can state that all relevant criteria were sufficiently considered, because no additional criteria came up during the planning and designing phase.

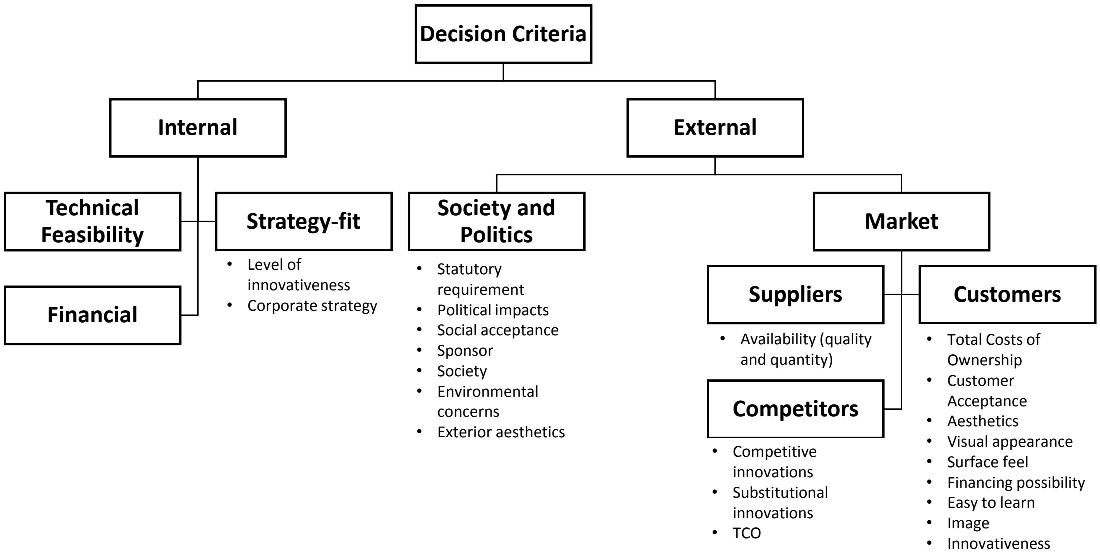

Figure 5: Identified Decision Criteria

Then, the product management weighted the categories and the criteria to each other. The weighted criteria are shown in figure 6.

		Decision Criteria	Criterion's weight	Block's weight	Total Weight
Internal	Block 1	Technical feasibility	90%	5%	5%
		Financial	10%		1%
	Block 2	Corporate strategy	50%	5%	3%
		Level of innovativeness	50%		3%
External	Block 3	TCO of competitors	60%	10%	6%
		Competitive innovations	30%		3%
		Substitutional innovations	10%		1%
	Block 4	Statutory requirement	50%	30%	15%
		Political impacts	40%		12%
		Social acceptance	10%		3%
	Block 5	Total Costs of Ownership	30%	50%	15%
		Customer acceptance	20%		10%
		Image	15%		8%
		Perceived innovativeness	10%		5%
		Reliability and durability	10%		5%
		Quality and aesthetics	10%		5%
		Easy to learn	5%		3%

Figure 6: Weighted Decision Criteria

The internal decision criteria were only weighted by in total 10 %: Most relevant criteria come from company's environment like the customer or statutory requirements. From those categories and criteria, the requirements can be derived. The criteria weighting can serve as a reference for the budget allocation. Dependent on the departments' responsibilities for the weighted requirements, the budget might be allocated accordingly.

PSS planning has different requirements for integrating departments and their information flows than planning of tangible products. E.g., PSS-planning needs information from the After Sales department in an earlier stages, because it requires an integrated development of products and services from the scratch.

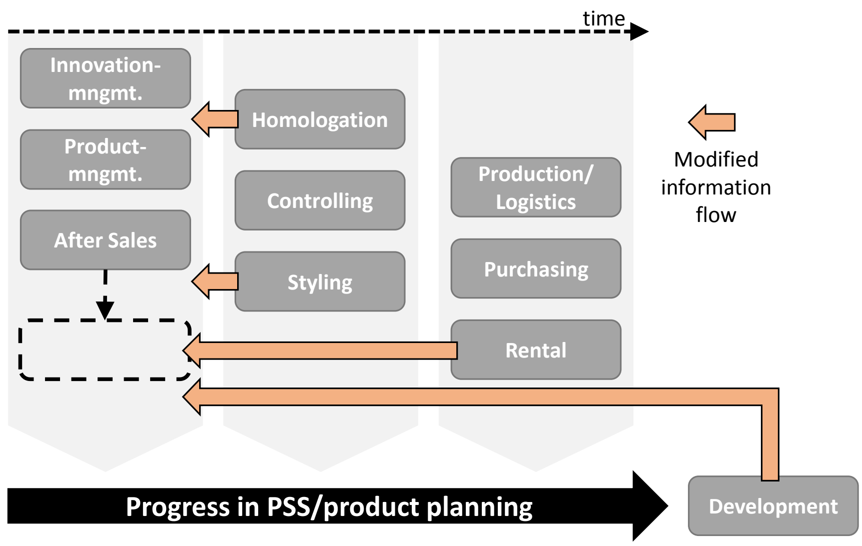

Figure 7: Information Flow of Departments in PSS Planning

In figure 7, we depicted the information flow between the departments in the product definition for initial situation (tangible product only) and optimized for planning and designing a PSS (modified information flow). Departments like “Rental”, “Homologation”, “Advance Development” and “Styling” have to be integrated earlier in the process to enable a suitable information flow for services, service innovations, components, requirements and technologies. The application of step 1 results in a requirements list and the optimized information flow. The R1-review of our process model (Schmidt et al., 2015b) sets the end of this step, which was successfully accomplished, while the relations of the requirements will be investigated more detailed in step 3, because the case study included a detailed consideration of all elements.

4.2 Step 2: PSS-Elements

Step 2 starts with an interdisciplinary workshop with participants from After Sales, Innovation management, market research and product management. The workshop resulted in a list of existing product and service components (from the previous generation) and a list of new and innovative product and service components (see table 1), which represent the PSS-portfolio. As the level of abstraction was too high at this moment, the connecting infrastructure was not relevant in this case and at this state in the planning phase. During the workshop, the product management regarded the strategy-fitness of the identified elements.

Table 1: Identified PSS-Elements

Product components	Product innovations	Services	Service innovations
• Combustion engine • Drive train • Tires • Cabin framing • Dashboard • Central console • Steering wheel • Mirror • Entrance • Door • Seats • Bed • Infotainment	• Tire pressure control system • Dual clutch transmission • Integration of tablet device • Office in driver's cabin • Range resolution • Maneuvering assistant • Electronic engine management • Start-stop automation • Smart cruise control • Electronic shaft • Hybrid engine	• Fleet-management software • Insurance • Financial services • Drive train repair contract • Full service	• Fuelwatch • Truck by Call • Networked Infotainment-system • Apps • Telematics • Prevention of empty runs

4.3 Step 3: Dependencies

In this step, we modeled the requirements, the functions, the components (service and product) and their inter-relations. For this, we used the software tool Soley Modeler, developed by Soley (www.soley-technology.com). Figure 8 shows the considered elements and their relations. To identify missing relations, we defined the necessary conditions.

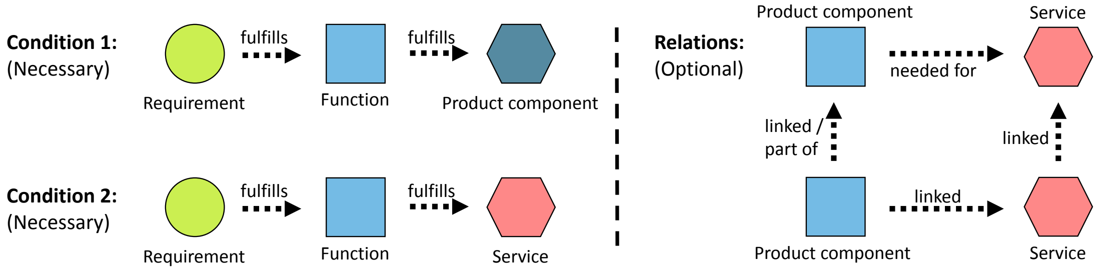

Figure 8: Elements of PSS-portfolio and their Relations

The PSS architecture including the PSS elements were modeled and they are depicted in figure 9. As we modeled both service and product components, the modularization of the product architecture has changed, compared to the product architecture based on the product components only. This kind of modularization is a more stable approach for modularizing PSS, as it also includes interrelations caused by services. Therefore, the modularization integrates interrelations between product and service elements. Identifying missing relations in this architecture reveals not fulfilled requirements or redundant components. After the identification of missing relations, we analyzed the architecture of the PSS.

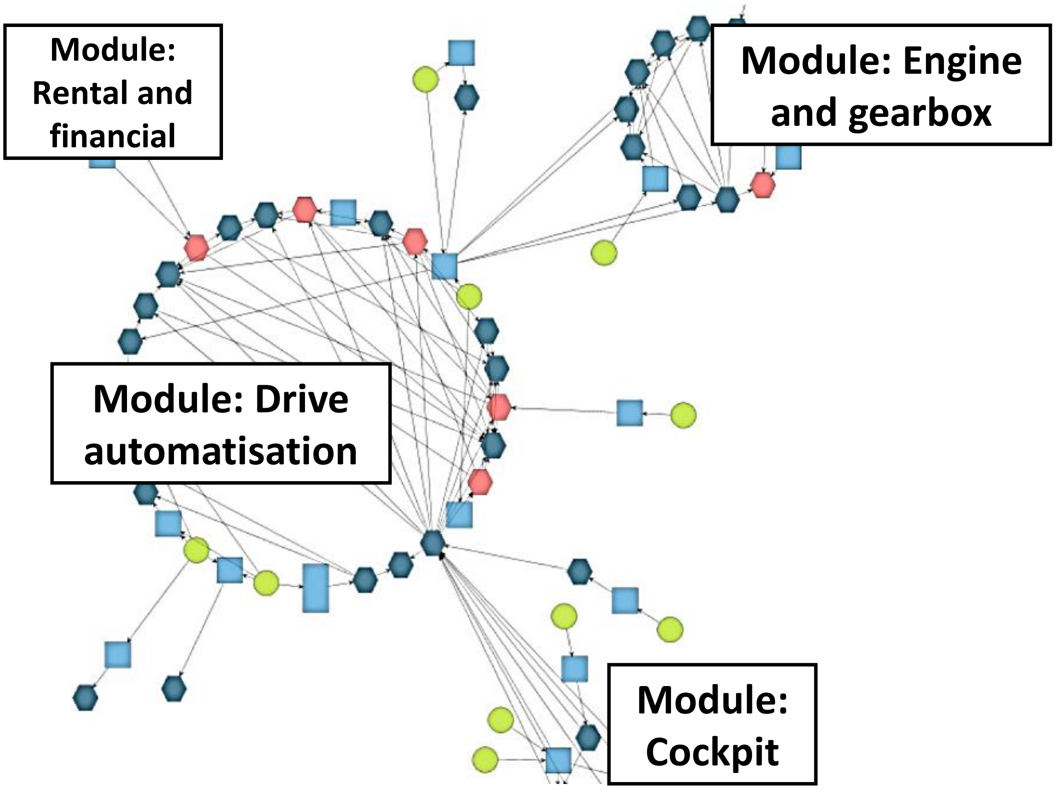

Figure 9: PSS architecture of the vehicle

For this, we first identified PSS-elements, which are critical regarding their connection to the architecture: Changing elements is more difficult and affordable, if they have too many relations, because all related elements have to be changed as well. Increasing the budget and efforts for those elements might increase the robustness of those elements. Furthermore, highly connected elements are interfaces between elements, which underlie the responsibilities of different departments. Knowledge from different departments is necessary for designing those elements. Another architecture analysis we conducted is the identification of product components supporting the same service. This reveals the needed integration of service developer into the development of product components.

Based on this PSS architecture, we assessed the dependencies of product components and services to each other. The number of relations of a product component to services determines the product component's dependency on services. The number of relations of a service to product components determines the dependency on product components. This measure will be used in step 5 to visualize the PSS concept and to show the dependencies of product components and services to each other.

4.4 Step 4: Uncertainties

In this step, we calculated the uncertainties of product components, technical innovations, services and service innovations, which were defined in step 2. We applied the method according to Kammerl et al. (2015) for determining the elements' uncertainties concerning the decision criteria. For this, we used factors determining uncertainty, like customer, competition or innovations, and calculated indirectly the elements' uncertainties concerning the decision criteria. The results are shown in figure 10.

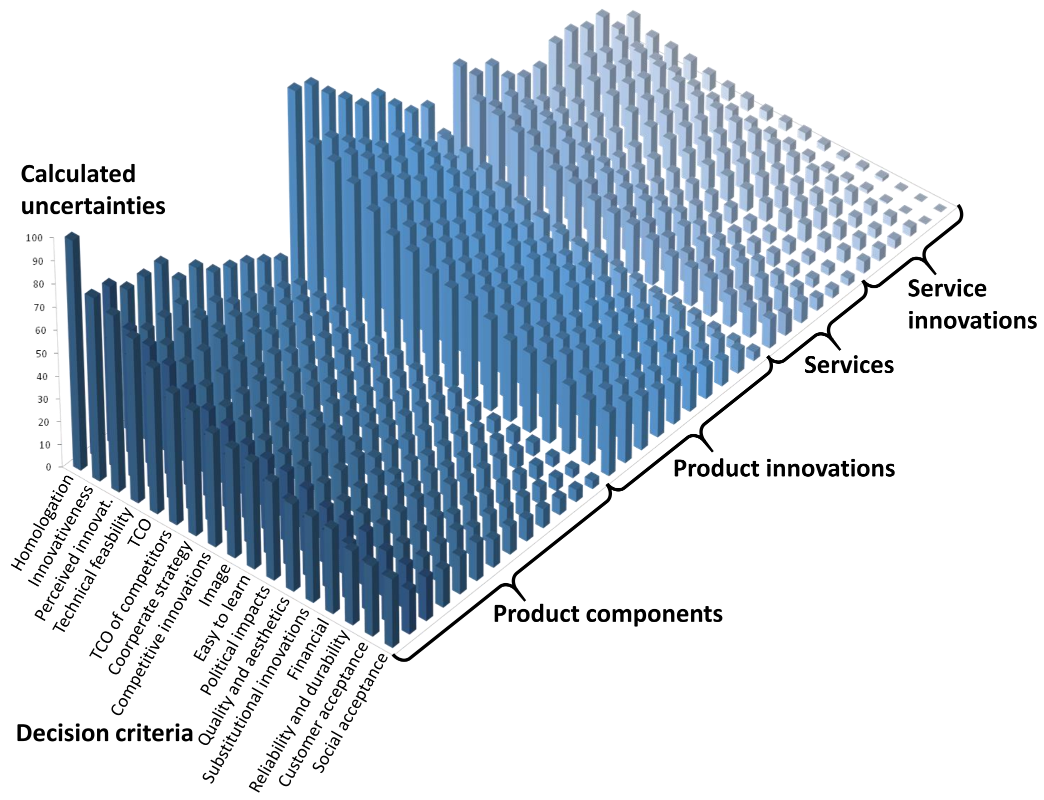

Figure 10: PSS Elements' Uncertainties

The uncertainties of the services and service-innovations are smaller than the uncertainties of product components and innovations. This is caused by the fact that most services are software-based and are created in an agile development, which means lower costs and efforts for changes.

The most uncertain product components are the combustion engine, the infotainment components and the digital mirror. They are most uncertain regarding the homologation, level of innovation, perceived innovation and technical feasibility. To reduce this uncertainty, the departments' innovation-management and development should increase their cooperation, as the innovativeness of developed products must be ensured.

The most uncertain product innovations were electronic shaft and office in driver's cab. A product innovation consists of several components. To illustrate the factor time on the expectable maturity of product innovations, we built a technology roadmap for the product innovations and their components. This roadmap shows successively the time steps for the realization of the components. This is a plan to handle product innovations' uncertainties: By allocating the innovations' components to different temporal horizons, the components' uncertainties will be allocated and reduced. This roadmap concretes a strategy to realize product innovations. The technology roadmap for our case study is shown in figure 11.

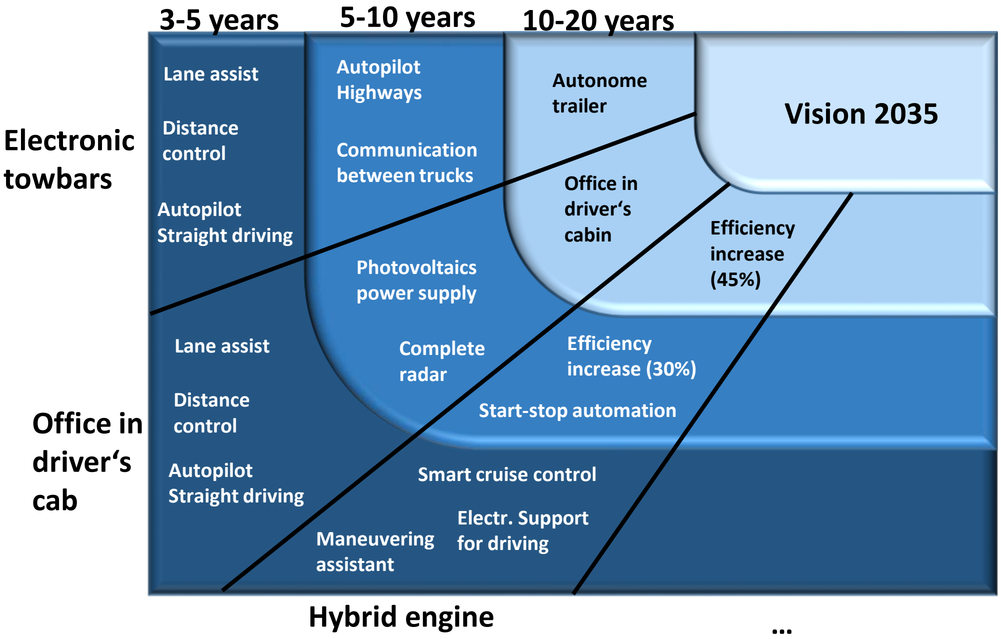

Figure 11: Technology Roadmap

4.5 Step 5: PSS-Concept

In this case study, we did not use the method for the compatibility analysis, because the elements' compatibility was not relevant enough. Instead of this method, we weighted the components regarding their necessity for realization. We used two kinds of relation to grade the necessity: For which and how many services is the product component needed for and for which and how many product innovations (consistent of one or more product components) is the product component needed. Figure 12 depicts those relations.

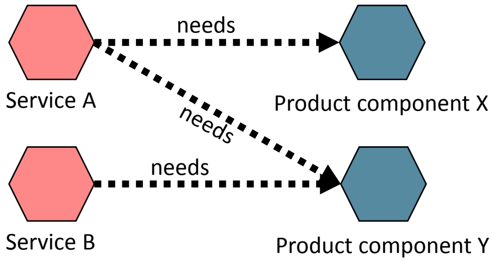

Figure 12: Relations between services and product components

Taking these relations into account, recommendation for realizing components were made. Some of them were recommended to realize because they are needed for many services or product innovations. E.g., the GPS Transmitter is needed for the services "fleet management software", "vehicle by call" or "fuelwatch". Other components which are needed for less services, might be offered as a special-feature, which must be paid by the customer with an extra amount of money. E.g. the sensor for tire pressure is relatively expensive but only needed for two services. As also the components' costs are relevant for the realization, some components were recommend to proof their cost effectiveness for deciding about the realization. This facilitates the definition of a concept which includes elements belonging to the standard equipment and optional elements. For visualization of a concept, we depicted the PSS-elements, ordered by services and product components and by the service- and product-dependency, which we have calculated in step 3. This PSS-concept is shown in figure 13.

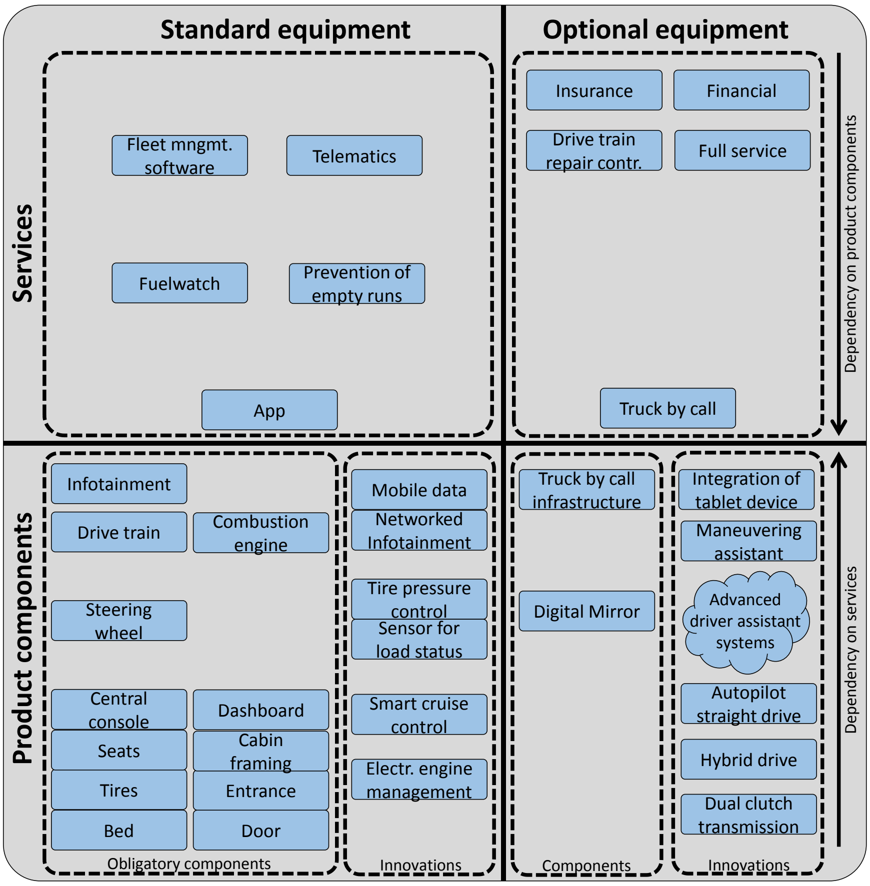

Figure 13: PSS-concept for the current generation

This visualization simplifies the selection of relevant elements and gives a clear and easy understandable representation of the concept. Using the technology roadmap from step 2, we also can define the PSS-concept for the next generation to plan the PSS cross-generational. This facilitates a long-term planning and realizing of product innovations, which are planned for the future but not realizable within a short-term period. This might reduce the future costs for changes, as innovations and their realization can be better planned. For our case study, we have defined two more concepts for the two following generations, which are shown in figure 14.

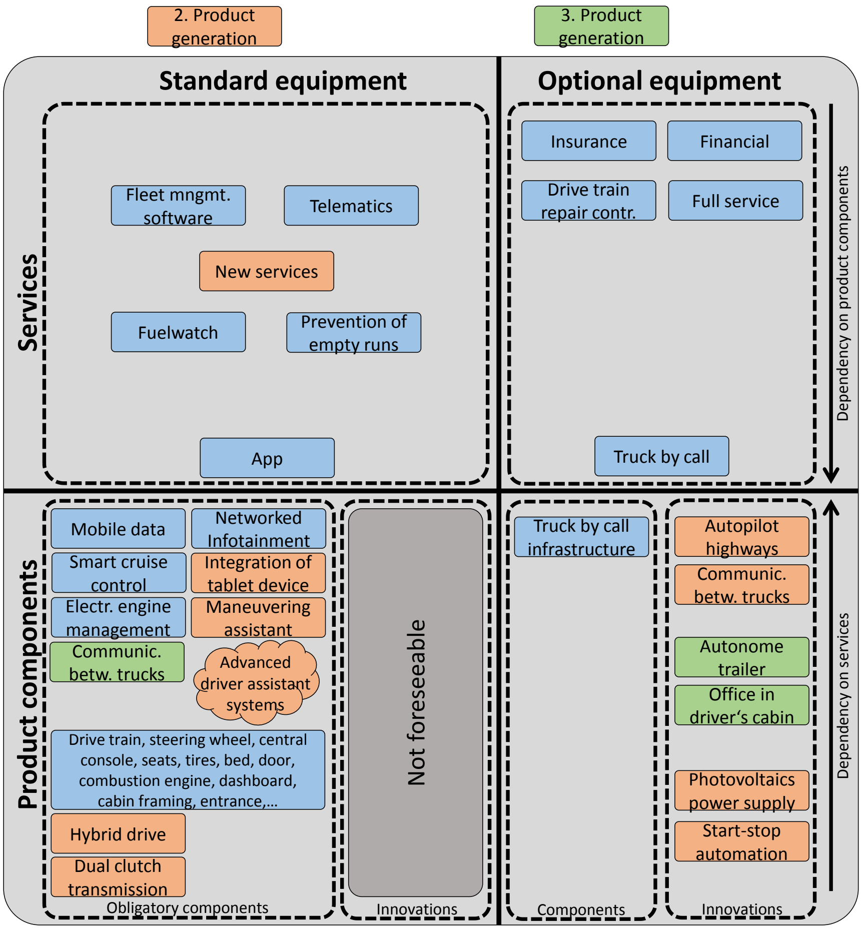

Figure 14: PSS-concept for the next and after next generation

4.6 Step 6: Quality Concept

The last step aims on the concept's quality which can be seen for ensuring the concepts before the actual design phase starts. One special attribute of our case study concerns the relation to the customer and the user. As the user (the driver) is not identical to the customer (vehicle owner), the drive must be able to perceive the product innovativeness, because also the driver essential for the purchase decision. This is caused in the fact that there is a lack of vehicle drivers and to increase the driver's motivation, he has a say in the purchase decision. For this, we first conducted a market research and compared our concept to competitive products based on Schenkl et al. (2013b). For this comparison, we used the quality criteria defined by Garvin (1987).

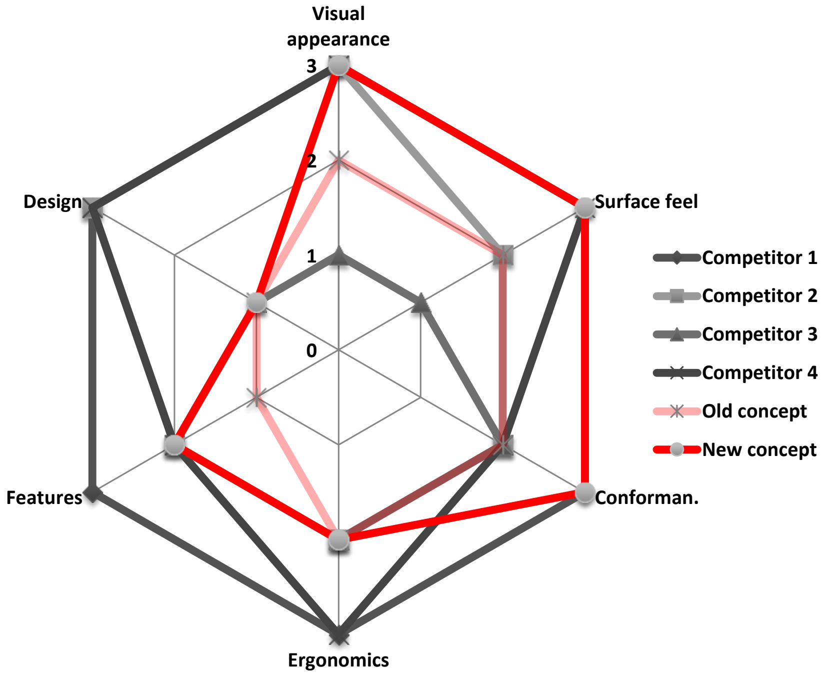

Figure 15: Comparison with competitive products

This research reveals that the company is just in the average compared to the competitors, even though the company wants the product to be best in dimension in three quality criteria. The aimed quality evaluation compared to the competitors is shown in figure 15. To reach this quality evaluation, costs and efforts for the design have to be invested. Using cost estimations for the product components and interviews with designers, we build a quality cost matrix, according to Schenkl et al. (2013b). The results of this matrix are shown in figure 16 as a portfolio-illustration.

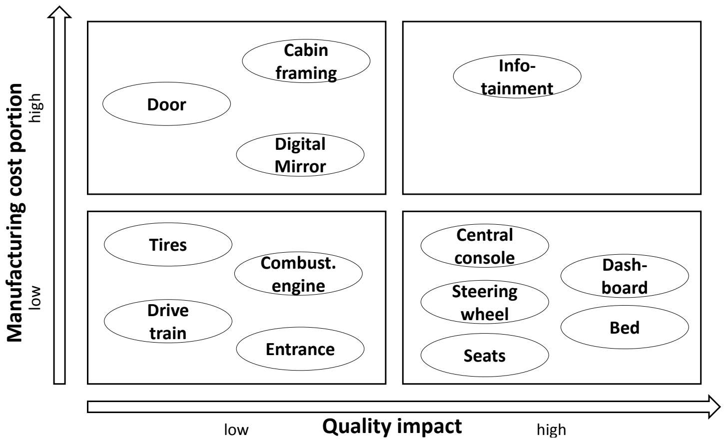

Figure 16: Quality-Cost Portfolio

As the dashboard, the central console and the steering wheel have a great influence on the quality perception. However, they are just planned to need a small amount from the budget. To ensure a high level of quality for those components, the budget for those components were increased. The door and the digital mirror influence the quality on a lower level, but they are planned with higher costs.

5. Conclusion and Outlook

In this work, we combined methods and a process framework for product planning to a consistent methodology for planning PSS. To evaluate the applicability, this methodology was used for the PSS-planning of a truck. The process model provided a suitable framework for the planning process. Even though it consists of clear defined parts and a consistent procedure, the case study application did not follow exactly the steps and reviews as they were originally defined. We conducted the step 3 (dependencies) after the step 4 (uncertainties), because the PSS-elements' uncertainties were earlier needed in the planning phase than the dependencies. This reveals that sequence of the steps of our methodology and of parts of the process framework is not a fixed sequence. As Schmidt et al. (2015b) stated in their work, the sequence depends on the situation.

Based on the situation some steps or methods might not be suitable or applicable. Step 1 might not be necessary for the following case: If it is about a further development and not a new product development, the product idea already exists and the decision criteria and their weighting of the previous development can be carried over. A planning process needs step 2 of our methodology, because this step defines all possible product elements. The PSS-portfolio of previous development might reduce the efforts of this step. The third step investigates the dependencies of PSS-elements. The more relevant the elements' relations (modularization, analyzing product architecture, great number of elements) are, the more accurate the dependencies must be considered. If the regarded PSS is of less complexity, considering the requirements fulfillment of the PSS-elements might be sufficient. Analyzing the uncertainties is essential for complex products, which are planned over the long term. The longer the development process takes time and the more planning horizons the planning process has to investigate, the more important is to handle uncertainties. The necessity of step 5 and the PSS-concept's level of detail depend on the product and on the input the development needs for concretization. The development process of certain products might not need a finalized concept, the PSS-portfolio might be sufficient. The PSS-portfolio also includes elements which are excluded for the finalized concept. In some cases, the development process might start without having a defined PSS-concept, as knowledge from the development supports to exclude not needed elements from the concept. In those cases, the development process starts on the PSS-portfolio and findings from the development influence the definition of the PSS-concept. Step 6 is to optimize the PSS-concept concerning the quality, however, it is for improving the product quality and not necessary for all situations.

The method for identifying and weighting decision criteria was successfully applied at the case study and it facilitated to consider the entirety of relevant factors influencing decisions about the products. This method first ensures that managers forget an important criterion. Second, the weighting of criteria raised the managers' awareness for considering criteria on an appropriate level. Without weighting the criteria, participating managers might neglect the fact the criteria should be considered according to their importance. Therefore, weighting criteria leads to better decisions.

Modelling the information flows and optimizing them according to the requirements for PSS-development supports the company to transform to a PSS-provider from the organizational perspective. To consider product components and services from the beginning of the planning phase, departments must cooperate in those early phases. Participated departments must be aware of it and must adapt their information flow accordingly. This method for organizing information flows makes the departments' structures fit for PSS-development.

The method for acquiring and visualizing the PSS-elements and their dependencies was helpful for a new modularization and for identifying missing relations. This kind of modularizations takes interactions between services and product elements into account. This way of modularization differs from classic approaches for regarding product architecture, which only focus the product components.

Modelling the PSS-concept over several planning horizons and visualizing these concepts enables the company for have a long-term planning of their products. The comparing visualizing of product components and services outlines the share of service and product. This helps product managers in their decisions, if additional services should be implemented. The consideration of more than one product generation simplifies the planning of the product strategy and details the strategy on the level of product components.

In total, we built a decision methodology, which fulfills the requirements of PSS-planning. As the PSS-architecture is more complex and more interrelated than products, our methodology includes the step of analyzing those interdependencies. The consideration of decision criteria and their weighting helps to include all relevant factors and to get along with the cyclical character of those criteria. The way of visualizing more than one product generation in building the PSS-concept faces those cycles of decision criteria and enables a suitable handling of those cycles.

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