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INFLUENCE OF DESIGN-FOR-X GUIDELINES ON THE MATCHING BETWEEN THE PRODUCT ARCHITECTURE AND SUPPLY NETWORK

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Abstract

Emerging global markets and fierce competition lead manufacturing firms to a transfer a large share of their value creation in development and production to suppliers that are arranged in a supply network. To prevail in this competitive situation manufacturing firms have to depend on the performance of their supply network, which is ideal for a matching between the product and its supply network.

Besides manufacturing firms apply certain design guidelines to improve time-to-market and production cost as well as ensure product quality. Those guidelines (Design-for-X) focus on specific characteristics (e.g. manufacturing, assembly, procurement …) of the design and have a significant influence on the matching between product architecture and supply network. To unveil the effects of design guidelines on the matching, this paper presents an overview of relevant Design-for-X guidelines and elaborates their influence on either the product architecture or the supply network. In essence, these guidelines employ four technqiues (modularization, standardization, simplification and partnership), which are applied to an academic case study to evaluate their internal validity and operability.

Keywords: Design for X (DfX), Product architecture, Concurrent engineering (CE)

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1 INTRODUCTION

Emerging global markets and fierce competition forced manufacturing firms to rethink their concept of cooperation (Nepal et al. 2012; Fixson 2005). This led to a transfer of value creation in development and production to suppliers that are arranged in a supply network (Bardi 2002). To prevail in this competition, manufacturing firms have to depend on the performance of their supply network, which is according to (Pero et al. 2010) ideal for a matching between the product and its supply network based on their structural characteristics. Literature provides a magnitude of approaches to support this matching, like a review provided by (Gan & Grunow 2013) or (Behncke et al. 2015). The latter provides a classification of approaches and stresses the relevance of the design space for the product architecture and the supply network. Thereby, most approaches provide guidelines or mathematical models that reveal an ideal match between the product architecture and supply network based on a set of different domains. (Gan & Grunow 2013) foster the ability to design the product architecture in parallel to the supply network, which promises an ideal performance of the entire supply network.

Besides manufacturing firms follow design guidelines to improve time-to-market and reduce production cost as well as ensure product quality. Those design guidelines (Design-for-X) focus on specific characteristics (e.g. manufacturing, assembly, procurement …) and therefore influence the product design as well as related domains. This influence affects the matching of product architecture and supply networks through the design space modification that is not elaborated in literature as most approaches focus on the matching process, while neglecting the appliance of Design-for-X guidelines. To unveil the effects of design guidelines on the matching, this paper presents an overview of relevant Design-for-X approaches and elaborate their influence on either the product architecture or the supply network to answer the research question of this paper, which is as follows: *How are Design-for-X guidelines influence the matching between product architecture and supply network design?*

1.1 Product Architecture

The product architecture (PA) represents a product in early phases of product development using three elements. Ulrich and Eppinger (Ulrich & Eppinger 2012) define the PA as assignment of a products' functional elements to their physical appearance. The latter is described by physical components, which are organized in building blocks. Furthermore, the overall functionality of the product is partitioned into sub-functions (1), which is the first of three steps suggested by Ulrich (Ulrich 1995) to define the PA. The second step (2) assigns physical components to the function structure of the product, while the last step (3) specifies the interfaces between interacting physical components (Ulrich 1995). Other highly referred literature defining PA report the same characteristics (Otto & Wood 2001; Göpfert 2009), so that the definition of PA by Ulrich and Eppinger (Ulrich & Eppinger 2012) and Ulrich (Ulrich 1995) is utilized through the paper at hand.

1.2 Supply Network

Supply Networks (SN) define the structure and organization of a multitude of suppliers. The referred definitions are an extract that are considered relevant for this paper, as they provide an overview of relevant domains and dependencies considered in SNs that might be affected by Design-for-X guidelines. SN describe the up- and downstream flow of material, capital, and information in order to fulfil the requirements of the ultimate costumer (Beamon 1998; Mentzer et al. 2001; C. & Xu 2009). Another characteristic of SN is its dynamics that arise due to the use of various interlinked suppliers (Chopra & Meindl 2013). Accordingly, a SN is defined as: "The SN is a dynamic network of manufacturing and distribution stages, connected by the up- and downstream of material, capital, and information with the finale goal to achieve a value-add for the ultimate customer" (Behncke et al. 2014).

2 RESEARCH METHODOLOGY

This paper presents an overview of Design-for-X guidelines that affect either the PA or SN design. These guidelines are result of an excessive literature review in several commonly used academic scholar databases using a variation of keywords like design guidelines, Design-for-X or DFX. A corner stone in literature is the resent paper presented by (Arnette et al. 2014) that provides an overview of design guidelines. Therefore, the excessive literature review in international journals that are related to product development and supply chain management was extended by a forward and backward search of references based on the work of (Arnette et al. 2014). Thereby, the inclusion of guidelines for the review (section 3) depended on, whether the guideline influences the structural characteristics of either the PA or the SN. Finally, the guidelines are applied to an academic case study to evaluate the internal validity and operability. The case study features a system with few elements to accent the comprehension of the solution space exploration of SCN and PA alternatives and their structural matching in favour for a system that is as close as possible to an industrial appliance.

3 OVERVIEW OF DESIGN-FOR-X GUIDELINES

Based on the classification of guidelines in terms of their characteristics presented by (Arnette et al. 2014), Table 1 summarizes guidelines considered relevant for the matching of PA and SN design. Thereby, guidelines are included that are considered sub-categories – illustrating the highest level of detail on the guidelines possible – as well as guidelines focusing on economic impact. The specific guidelines will be discussed in detail throughout this chapter.

Table 1. Design-for-X Guidelines and used Abbreviations

Design-for-X Guideline	Abbreviation for Guideline	Number of Guidelines from Literature Review		
		Relevant	**Irrelevant**	**Total**
Modularity	DFMod	4	2	6
Mass Customization	DFMaCu	2	6	8
Maintainability	DFMt	3	8	11
Serviceability	DFSv	1	2	3
Assembly	DFA	3	10	13
Manufacturing	DFM	3	5*	8
Logistics	DFL	2	11	13
Procurement	DFP	2	6	8

* DFM covers a number of generic guidelines, followed by rules for specific manufacturing processes that are not considered relevant as there is no influence on the structural characteristics of either the PA or the SN.

3.1 Design for Modularity

DFMod supports the development of modular products and processes. It is used to reduce the complexity of a system by separating it into small chunks (Ulrich 1995; Loch et al. 2003). Modularity is seen as a key driver of concurrent engineering, since it enables simultaneous development and procurement of modules. Thereby, DFMod promises an increase product variety and flexibility combined with reduced assembly time as well as costs (Arnette et al. 2014). However, to achieve those benefits modular independencies require a clear decoupling of modules and specification of interfaces.

DFMod 1 – Module independence: This guideline demands to design independent modules with explicit interfaces that act together as a whole product. It is advantageous to re-use already existing modules as long as they do not compromise the integrity and the nature of the product. (Göpfert 2009; Ulrich 1995; Bi & Zhang 2001)

DFMod 2 – Component independence: The second guideline of DFMod focuses on the dependencies of components and aims for a limited link of components within a module to other modules or components of the product. (Arnette et al. 2014; Gershenson & Prasad 1997)

DFMod 3 – Process Independence: In order to utilize the ultimate benefits of modular products, the production process of modules may not share any connection to each other. (Gershenson & Prasad 1997)

DFMod 4 – Process Similarity: Components that share the same production process may be assigned to the same module. This allows to join the processes and capsule changes, as they propagate to the components in the same manner. (Gershenson & Prasad 1997)

3.2 Design for Mass Customization

DFMaCu is a set of guidelines that support companies to implement the paradigm of mass customization. Its emphasis is on designing a family of products rather than designing an individual product (Zha et al. 2005; Tseng et al. 1996). The objective of DFMaCu is to provide products and services that fulfil customers' requirements with near mass production efficiency (Zha et al. 2005; Jiao et al. 2003; Tseng et al. 1996; Tseng & Du 1998).
DFMaCu 1 – Integrate with key partners: This guidelines is founded on establishing relationships with key partners. Especially the integration of suppliers of customer-specific modules is indispensable for a functioning mass customization. This includes the development of information systems between the OEM and its suppliers, which help to shorten delivery time, increase responsiveness and reduce costs. (Osorio et al. 2014; Silveira et al. 2001; Duray et al. 2000; Skjelstad et al. 2005)
DFMaCu 2 – Establish modular products: Mass Customization is implemented by arranging products in product families, which share a basis of modules within each of the product families. The guideline emphasizes the need for standardized modules that are not needed to satisfy customer's requirements, in order to simplify the development of those product families. Additionally, it suggests to make a product program that summarizes the product families into product platforms for further simplification of the supply chain and procurement of the mass customized products. (Duray et al. 2000; Osorio et al. 2014; Skjelstad et al. 2005; Zha et al. 2005; Tseng et al. 1996)

3.3 Design for Assembly

DFA aims at reducing the handling, fastening and insertion time (Boothroyd et al. 2010; Emmatty & Sarmah 2012) and thereby reduces costs for assembly (Sik Oh et al. 1995). In general, assembling a product means that "[…] a person or machine (1) retrieve components from storage, (2) handle the components to orient them relative to each other, and (3) mate them." (Ullman 1992). High assembly times often occur with complex systems, which have been developed without considering the assembly process (Sik Oh et al. 1995).
DFA 1 - Reduce part count and types: In order to reduce product complexity, reducing the overall part count of a product seems to an appropriate measure (Boothroyd et al. 2010; Emmatty & Sarmah 2012; Ullman 1992). Thereby, this reduction promises a decrease of assembly activities and avoids errors in the assembly (Huang 1996; Dowlatshahi 1996).
DFA2 – Standardization: Besides a part count reduction, parts are redesigned for the ease of insertion and fastening. There are many ways to achieve this goal, for example by making minimum use of separate fasteners or by using chamfers, leads and compliance to facilitate insertion and alignment. The crucial principle in improving the design for insertion and fastening is the need for standardization. Using common parts, processes and methods across all models and even across product lines can shorten the assembly time (Booker et al. 2005; Boothroyd et al. 2002; Miles et al. 1998; Ullman 1992; Ulrich & Eppinger 2012)
DFA 3 – Modularization: The last principle to support the design for assembly is the utilization of pre-assembled modules that promise a significant reduction of assembly time (Huang 1996).

3.4 Design for Manufacturing

DFM is the DFX concept that seeks to identify the appropriate materials and processes for component parts being considered in a product's design (Bralla 1998). It was defined by (Stoll 1990) as "the full range of policies, techniques, practices, and attitudes that cause a product to be designed for the optimum manufacturing cost, the optimum achievement of manufactured quality, and the optimum achievement of life-cycle support, serviceability, reliability, and recyclability."
DFM gained importance among manufacturing companies for improving productivity without additional investments (Fabricius 1994).
DFM 1 – Simplification: Designing for the ease of manufacturability means simplifying the product design by reducing the overall part count and by shortening the manufacturing sequences. If for example varnishing a component is not needed to secure its reliability, it should be omitted. (Anderson 2004; Bralla 1998; Kuo & Zhang 1995; Miles et al. 1998)
DFM 2 – Standardization: Another general rule in Design for Manufacturability is the standardization of materials and components. This means only using widely available materials and off-the-shelf parts and standard components. Both recommendations reduce the costs for procurement significantly. It is

also beneficial to implement a modular product architecture in order to simplify manufacturing activities such as inspection, testing, purchasing, maintenance, and so forth. (Anderson 2004; Bralla 1998; Kuo & Zhang 1995; Ulrich & Eppinger 2012)
DFM 3 – Rationalise product design: The last DFM guideline expands the focus to product families and suggests the utilization of similar materials, components and sub-assemblies in a product family to reduce tooling costs. Furthermore, the guideline earmarks the generation of variants enabled by a modular product architecture design. (Huang 1996)

3.5 Design for Procurement

DFP is a concept that supports product design engineers to develop products for the ease of simple procurement operations. Many product design based decisions have a great impact on the complexity of procurement operations. Therefore reconciliation of product design and procurement promises an improvement of performance for the entire company (Pulkkinen & Martikainen 2011).
DFP 1 – Simplification of design: The guidelines of Design for Procurement suggest that a simplification of the overall design can already lead to significant cost savings. To achieve a simpler design the rules advise designers to reduce the overall part count and to standardize components. (Pulkkinen & Martikainen 2011)
DFP 2 – Modularization: Another guideline of DFP suggest to develop modular products. Modularity enables the procurement of complete modules which reduce inventory and transportation costs significantly. Moreover, modular products support outsourcing of entire modules. Additionally the guidelines advice the introduction of product families and platforms to achieve communality across components to simplify the purchasing operations even more. (Pulkkinen & Martikainen 2011)

3.6 Design for Logistics

DFL represents an approach for the holistic optimization of the costs for logistics as well as the enhancement of the competitiveness of products and the company's productivity (De Weck et al. 2011). Its aim is to coordinate and converge the differing and contradicting objectives of designers and logisticians in the product development process (Emmatty & Sarmah 2012; Göpfert 2009).
DFL 1 – Enable parallel processing: Since manufacturing operations and schedules have a large impact on logistics, it is necessary to design for concurrent and parallel processing. Parallel processing can be enhanced by developing a modular product and by outsourcing the manufacturing of components and modules that do not belong to the core competences of the firm. (Dowlatshahi 1996; Lee 1993; Gatenby & Foo 1990; Simchi-Levi et al. 2014)
DFL 2 – Reduce amount of parts: Additional simplification of logistics operations can be achieved by the standardization of components and the reduction of the overall part count. Developing product platforms and families further lowers the complexity of the inventory since only a restricted number of parts are needed for every product listed in a company's product portfolio. (Dombrowski et al. 2006; Dowlatshahi 1996; Ernst & Kamrad 2000; Lee 1993; Simchi-Levi et al. 2014; Gatenby & Foo 1990)

3.7 Design for Maintainability

DFMt increases „the ease with which a product can be maintained, and with proper maintenance, the life of the product can be extended" (Arnette et al. 2014). Thereby, the major objective is to allow the perfective maintenance.
DFMt 1 – Standardization: Standard components supports the replacement of defective components. Furthermore, it allows the use of standard tools in maintenance and reduces the number of required spare parts significantly. (Arnette et al. 2014; Moos 1985)
DFMt 2 – Modularization: Modularization enables this guideline, as modular products promises to replace an entire module in maintenance with less resources (Moos 1985).
DFMt 3 – Functional Packaging: This guideline is founded on the integration of components that are relevant for specific product function in one module. This integration allows a more distinct cause analysis of failures and therefor accelerates the repair of products. Moreover, the replacement of those modules is supported according to the DFMt 2. (Kuo et al. 2001; Moos 1985)

3.8 Design for Serviceability

DFSv, "focuses on methods for improving serviceability during the product design stage for the benefit of the consumer and the company". Key performance indicators for DFSv are time and costs of service activities. (Arnette et al. 2014)

DFSv 1 – Reduce the use of separate fasteners: Utilizing separate fasteners increases the part count, which raises the number of required assembly steps. In the same amount DFA is driven by assembly steps, DFSv is driven by disassembly steps. As a result, this guideline grasps for a reduction of separate fasteners to save assembly steps, so that time and costs for service activities may decrease. (Huang 1996)

3.9 Techniques of Design-for-X guidelines

As there are many recurrences between guidelines of the different Design-for-X concepts, table 2 illustrates the underlying techniques that influence the matching of PA and SN. Thereby, four different techniques represent the essence of Design-for-X concepts. The first technique is modularization that includes eleven guidelines, where seven suggest modularization as enabler (**) while four guide designers to develop modularized product or product family. Standardization is utilized by 3 Design-for-X guidelines that deal with the assembly, disassembly and manufacturing of the product. Another essential technique is simplification of the design that foresees a part count reduction in its core. Thereby, Modularization, Standardization and Simplification set the boundary conditions of the PA design. The last technique focuses on the boundary conditions of SN design in contrast to the others that influence the PA as well as the SN. Partnership deals with the collaboration and integration of key partners in the product development process.

Table 2. Techniques of Design-for-X guidelines

Technique	Guideline Ref. No.	∑
Modularization	DFMaCu 2**, DFA 3**, DFP 2**, DFMt 2**, DFMod 1, DFMod 2, DFMod 3, DFMod 4, DFMt 3**, DFM 3**, DFL 1**	11
Standardization	DFA 2, DFM 2, DFMt 1	3
Simplification	DFM 1, DFP 1, DFA 1, DFL 2, DFSv 1	5
Partnership	DFMaCu 1	1

4 IMPACT OF TECHNIQUES ON THE MATCHING OF PRODUCT ARCHITECTURE AND SUPPLY NETWORK

The impact of these techniques on the matching of OA and SN is carried out by an academic case. The case study features a product (ballpoint pen) with few elements to accent the influence on the matching of PA and SN in favor for a product that is as close as possible to an industrial appliance.

4.1 Description of the case study: Ballpoint pen

The ballpoint pen consists of eight parts. The housing is made of two plastic parts bolted together and beld by a ring at the predefined distance. The clip for the attachment of the pen (No. 4) is inserted into the plastic housing. The mechanism for extending and retracting the mine is determined by the two-part knob at the upper end of the pen (No. 6 and No. 7). The mine (No. 8) is held by the spring (No. 5) in the correct position. This spring also serves the function of retraction and extension of the mine. Table 3 lists the components as well as their suppliers (L1 to L7) involved in the manufacture of the pen.

Table 3. Parts list of ball pen including suppliers

Number	Title	Supplier	Number	Title	Supplier
No. 1	Headpiece	L4 (L1)	No. 5	Spring	L6 (L2)
No. 2	Pod	L4 (L1)	No. 6	Connecting piece	L1
No. 3	Ring	L5 (L2)	No. 7	Knob	L1, L5 (L2)
No. 4	Clip	L5 (L2)	No. 8	Mine	L7 (L3)

The front section of the ballpoint pen (M1) is composed of the spring (No. 5) and mine (No. 8). For the rear part of the pen (M2), the clip (No. 4) is attached to the pod (No. 2) and connecting piece (No. 6) and the preassembled knob (No. 7) are loaded in the pod (No. 2). The ultimate product is assembled through fitting the ring (No. 3) to the module 1 and screwing the two modules. Figure 1 shows the given product architecture (left) and the supply network (right) of the ballpoint pen.

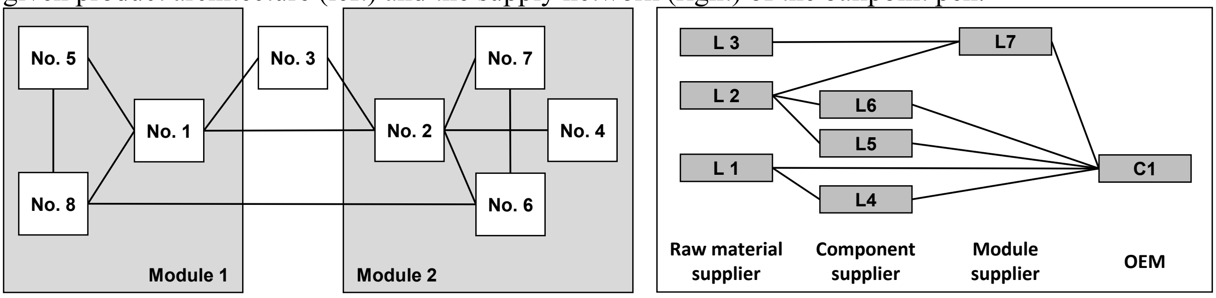

Figure 1. Product architecture and supply network of the ballpoint pen

The supply network of the ballpoint pen consists of seven suppliers (Figure 1 right). The supplied components are used by the Original Equipment Manufacturer (OEM) for the manufacturing of the pen (C1). Suppliers L1, L2 and L3 represent raw material suppliers, where L1 supplies the plastic granules, L2 the raw metal and L3 the ink for the mine. Supplier L1 supplies the component supplier L4, which produces the housings for the OEM. Besides, L1 delivers the plastic part of the knob and connecting piece directly to the OEM. L2 supplies the component suppliers L5 and L6 with raw metal, which is further processed by L5 to the Clip and to the upper part of the knob and is formed to the spring by L6. The module supplier L7 creates the mine from the raw materials from the suppliers L2 and L3.

4.2 Impact of techniques and application on the case study: ballpoint pen

The impact of the techniques are described in detail throughout this section for the ballpoint pen. The techniques are divided according to their impact within boundary conditions of the PA and SN design.

Boundary conditions of the PA design:

Modularization – This technique request for the design of modules with distinct interfaces within a product and across product families (DFMaCu 2 and DFM 3). Modules and its components are independent from other modules or components (DFMod 1 and DFMod 2) and thereby promise a significant reduction of assembly time (DFA 3) through a parallel processing (DFMod 3and DFL 1). In the phase of maintenance, modularization enables the replacement of an entire module with less resources (DFMt 2). In terms of the PA, modularization is affecting the arrangement of components into modules. The assignment of components to functions, functions to functions as well as components to components are not affected. So this technique has no influence on the PA in a closer sense, however the assignment of components to modules is affected by different guidelines, which represents the solution space of PAs. Due to different objectives of the guidelines the definition of modules might stand in conflict to each other, so that specific PA alternatives might be excluded from the solution space. This represents a limitation of the solution space of PAs. For the ballpoint pen this technique results in the definition of modules. Thereby, components No. 1, 3, 5 and 8 are assigned to one module (head of the pen), while the remaining components are assigned to a second module (back of the pen). These modules are not independent, but share just three different dependencies through distinct interfaces. There are several other PA alternatives to choose from, however this alternative seems to best fit most of the guidelines grasping for modularization.

Modularization allows the procurement of complete modules and therefore supports outsourcing. This influences the arrangement of suppliers in the SN. Moreover, the procurement of complete modules request more competences by suppliers as they have to take responsibility for more physical components as well as the management of an entire SN. This limits the number of potential suppliers in the supplier base and therefore limit the solution space of the SN. As a result, the PA alternative with two modules requires a SN with two module suppliers in order to reach a best structural fit between the PA and SN. This demands for a wider range of competences, which limits the number of suppliers to choose from. As a result, modularization limits the matching between the PA and the SN significantly.

Standardization – This technique grasps for a decrease in the variety of components used in products or product families (DFA 2 and DFMt 1), which concerns shape and condition of the component. Moreover, the standardization aims for the utilization of common materials (DFM 2). In terms of the influence on the matching between PA and SN, standardization limits the solution space of different PAs as it suggests the use of standardized components that have specific interfaces. The interfaces limit the ability of these components to be combined with other components, so that the configuration of the PA is limited. As a result, standardized components determine significant areas of the PA through their interfaces. The ballpoint pen already have standardized components like the spring (No. 5) or the mine (No. 8). Further standardization attempts might include the headpiece (No. 1) or the pod (No. 2) as they have numerous dependencies. The application of this attempt to the ballpoint pen determines wide areas of the PA, so that the solution space of PAs is limited significantly.

In terms of the SN, standardization allows the use of exchangeable suppliers. This fosters competition among suppliers and creates a wide base of suppliers for the specific component to choose from. Therefore, standardization supports the configuration of SNs as long as suppliers poses the required competences. The standardization of the headpiece (No. 1) or the pod (No. 2) allows to inquire a wider base of suppliers for quotation. This expands the solution space of SNs and therefore increases the possibility to find a best fit – based on structural characteristics – between the SN and the PA. As a result, the effect of standardization on the matching between the PA and the SN is ambivalent.

Simplification – The essence of simplification is a part count reduction that promises a shortening in the manufacturing sequence (DFM 1) and logistic operations (DFL 2) as well as a decrease in assembly activities (DFA 1 and DFSv 1). Assuming that the costumer request a specific product functionality a part count reduction leads to an integration of product functions in less components. This influences the nature of the PA significantly, as it influences the assignment of physical components to product functions as well as affects the interfaces between interacting physical components. Simplification reduces the solution space of the PA through less physical components for the configuration. For the ballpoint pen, this leads to the integration of the ring (No. 3) into the headpiece (No. 1).

In terms of the SN, simplification leads to the procurement of less components. This technique requires less activities in purchasing due the part count reduction. However, the integration of more product functions in less physical components challenge the competences in purchasing as more complex components are requested for procurement. Therefore, the efforts for simplification need to be joined with standardization to achieve significant impact (DFP 1). Simplification reduces the solution space of SNs as less suppliers in the supplier base might be equipped with the required competences to provide components that integrate more product functions. For the ballpoint pen, the integration allows a part count reduction, which requires a wider set of competences from potential suppliers. This might ask for a supplier development so that supplier L4 or L1 can manufacture the ring (No. 3) or supplier L5 or L2 manufactures the headpiece (No. 1). As a result, simplification limits the matching between PA and SN.

<u>Boundary conditions of the SN design</u>:

Partnership – The last technique describes partnership, which means in essence the integration of key partners early in the development of the product (DFMaCu 1). This integration is not affecting the PA as neither the physical components nor the functions and their assignment is affected.

Partnership affects the configuration of the SN, as an integration of key partners limits the number of potential suppliers. Integration of key partners is a strategic decision in purchasing, where competition among potential suppliers is abandoned in favor for an intensive collaboration with few suppliers. Besides, partnership influences the time, when suppliers are assigned. Partnership affects the evolution of the SN as well as the SN itself. As a result, this technique moderately influences the matching between PA and SN, as it limits the solution space of SNs. As there are no further information on the supply strategy of ballpoint pen available, the influence of this technique is not applied to the case study.

The four techniques including the underlying Design-for-X guidelines have a distinct impact on the design space for the PA and the SN as discussed above. Figure 2 illustrates the relations between the different techniques in scheme.

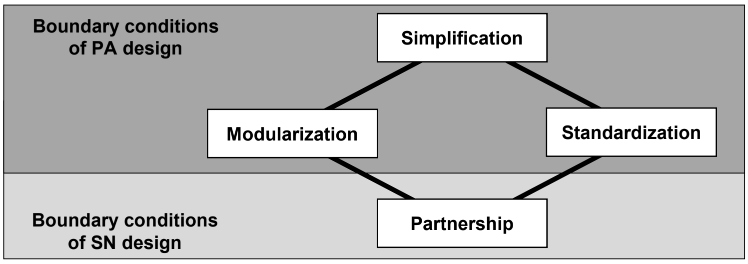

Figure 2. Product architecture and supply network of the ballpoint pen

5 CONCLUSION AND OUTLOOK

This paper elaborates the impact of Design-for-X guidelines on the matching between the PA and SN. Thereby, the guidelines utilize in essence four different techniques (modularization, standardization, simplification and partnership) to influence either boundary conditions of the PA or the SN design. This influence as well as the entire matching between PA and SN presumes that a significant share of the value creation is located in the SN. Furthermore, this paper focuses on the impact of Design-for-X guidelines on the matching between PA and SN based on structural characteristics. This assumption excludes trade-offs between the PA and SN that refer to detailed and dynamic attributes of the matching in favour for a detailed analysis of architectural attributes (Gan & Grunow 2013). The paper at hand focuses on this level of attributes as it promises the biggest impact on the matching between the PA and the SN as well as correlates with the common appliance of Design-for-X guidelines within the product development process. In order to prove the validity and operability of these techniques, they are applied to an academic case study (ballpoint pen). The case study underlines the challenge to apply the techniques to an industrial case study with its various facets, while revealing the precise impact on the matching between the PA and the SN. This limitation draws the research agenda that focuses on the application of the techniques to a case study from industry as well as a detailed investigation of the extend by which these techniques influence the matching between the PA and the SN.

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