Chapter 2
Product-Service System Approaches
A Business Perspective on Service Modeling

Daniel Beverungen, Martin Matzner, Oliver Müller, and Jörg Becker

Abstract For some time, increasing importance is attached to services, both from an economical and a managerial perspective. First, the notion of "service as basic unit of exchange" emphasizes the application of specialized competencies for the benefit of someone else, while disregarding if a physical good or any other resource is used for exchanging value. Second, service-orientation allows enterprises to enter new markets by extending their existing portfolio of products by related services or realizing entire new offerings that are enabled by recent advances in information technology. Service description is a key challenge in developing and providing services to and with customers. Further it is a premise for coordinating several providers of an integrated customer solution. This chapter is an effort to explain how conceptual modeling can facilitate service description. We use Product-Service Systems (PSS) as an exemplary domain. We extract central concepts from several disciplines that are engaged in researching business aspects of PSS to develop a catalogue of modeling requirements to be accounted for in service description. Consecutively, these requirements are utilized to assess the current state of conceptual modeling languages for (product-related) service description. The review leads to the identification of further prospects to be accounted for by service description.

Jörg Becker, Martin Matzner, Daniel Beverungen
University of Münster, European Research Center for Information Systems, Leonardo-Campus 3, 48149 Münster, Germany, e-mail: firstname.lastname@ercis.uni-muenster.de

Oliver Müller
University of Liechtenstein, Martin Hilti Chair of Business Process Management, Fürst-Franz-Josef-Strasse, 9490 Vaduz, Liechtenstein, e-mail: oliver.mueller@uni.li

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2.1 The Need for Conceptual Modeling of Services

2.1.1 The Trend Towards Service

Services have had a lasting effect on last decade's business development. From an *economical perspective*, we have been witnessing a transition from a primarily goods based to a more and more service-based economy in most developed countries [53]. Today, services are ubiquitous and they account, for example, for more than 80% of the gross domestic product (GDP) and total employment of the United States and about 70% of the GDP in Germany [15, 38, 74]. These figures reflect a development that has been prescribed by Vandermerwe and Rada under the term "Servitization of Business." In their understanding "servitization" refers to the increasing offer "of 'bundles' of customer-focused combinations of goods, services, support, self-service, and knowledge" [83, p. 314] — with services dominating the bundles. As an umbrella term the notion of 'service' has been coined as "the application of specialized competencies, through deeds, processes, and performances for the benefit of another entity or the entity itself." [84, p. 2] They coined 'service' to be the new basic unit of exchange in economies [84, 85, 86].

From a *managerial perspective*, enterprises at the same time struggle to efficiently provide adequate services to their customers. In order to generate superior business returns and as a result of ever increasing competition, companies face the need to specialize on their core resources and core competencies. However, at the same time they need to address complex business needs of their customers. Previous research [44, 69] has stated that the formation of relational ties and networks with further suppliers is a viable means for addressing both needs at the same time.

Though the service sector now accounts "for most of the world's economic activity, [...] it's the least-studied part of the economy" [73, p. 71]. Consistent with this is the observation that still no general consensus of the structure and nature of services has been reached (cf. [26] and also Chapter 4). In the recent past, researchers from different disciplines have so far investigated the phenomenon from rather distinct angles, e.g., from an economic, business, or technical perspective [4]. Only recently, an interdisciplinary research effort under the headwords of Service Science or Service Science Management and Engineering (SSME) has been emerging.

2.1.2 Beyond Goods and Services: Customer Solutions as Value Offers

Accordingly, many industries are today experiencing a transition from a goods-based to a service-based focus: Traditional manufacturing companies strive to provide physical goods and services as integrated customer solutions [23], which are delivered in relational processes with customers [82].

Physical goods and services are no longer perceived to be dichotomous [25]. Instead they are rather seen as complementary vehicles to offer value propositions to customers [84, 85]. This trend is especially recognized in the German Mechanical Engineering and Electrical Engineering industries. Evaluating results from two broad empirical studies in both sectors, Stille concludes that turnover related to services has doubled in the Electrical Engineering sector from 9.6% (1997) to 18.5% (2000), while significant gains from 16.8% (1997) to 22.5% (2000) could be identified in the Mechanical Engineering Sector [76]. Mercer Management Consulting points out, that half of the growth in German Mechanical Engineering in the years 1998–2003 can be allocated to exploiting the potential of the service business. Likewise, the margin realized in the service business (10%) was estimated to be significantly higher than the margin realized in the physical goods business (2.3%). Furthermore, Mercer states that margins gained from services could be even higher when looking at some leading edge services only, which constantly catch margins of up to 18% [50]. Additional empirical research shows, that companies attribute a high (38.1%) or very high (59.8%) impact on their revenues to their service business. Services are also seen as a good means for differentiation from competitors as well as for customer retention [23]. Consistent with these findings, 94.9% of the examined companies plan to expand their business by offering customer solutions [77].

Unless the matter still is heavily debated, the following characteristics have been proposed for customer solutions:

- Customer solutions comprise separately marketable tangible goods and intangible service which are purposefully combined to solve a problem for a customer or for a group of customers [23].
- Physical goods components and service components might (but need not) be substitutable with other components without changing the solution provided [23].
- For customers, outcomes of the solution can have tangible and intangible effects. One goal of providing customer solutions is to create an outcome for customers and/or providers which is superior to the simple sum of outcomes of the components [23]. In the end, the value of a solution is co-created by the supplier and the customer by integrating resources with other resources; the value realized from this relational process is, therefore, determined by each of the parties [86].
- Customer solutions are value propositions offered by the supplier to a customer. If a value proposition is accepted by a customer, customer solutions are co-created in service processes that are closely integrated with the customer's business processes and, therefore, require customer input (such as information, objects, personnel or other resources) [85].

Services which are often offered as part of customer solutions may correspond to different stages of the traditional product lifecycle, such as a start-up, operation or disposal stage (cf. Fig. 2.1). Services in the start-up stage may constitute pre-sales services such as engineering, consulting or technical assembly. During the operation stage, service activities such as preventive maintenance, corrective maintenance or spare parts logistics are mainly conducted to uphold the operability of the physical

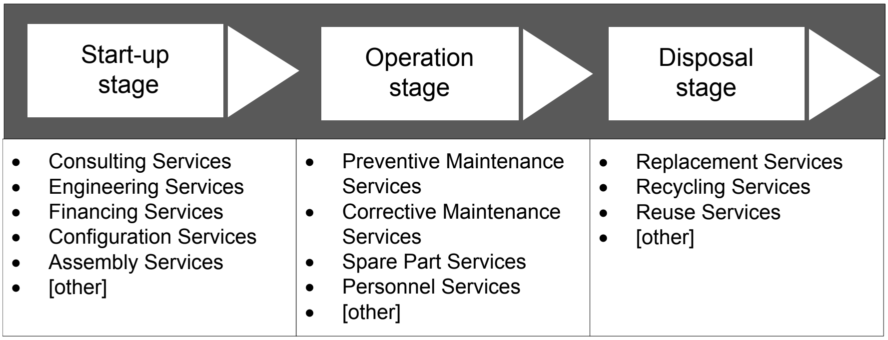

Fig. 2.1: Exemplary services, arranged with respect to a traditional lifecycle of physical goods.

good. Referring to the disposal stage, any of the physical goods components might be replaced, refurbished and reused, or recycled.

In practice, the most widely offered services in industrial settings are spare part logistics, preventive maintenance/fault repair, consulting, and assembly. It is striking, that most of these services are in fact not new and have a strong physical goods focus. In contrast to this, highly innovative services such as capacity management in value networks, performance contracting business models, or on-demand personnel provision are as yet seldom offered.

Some topologies have been proposed to grasp the characteristics of integrated physical goods and services, most notably by Engelhardt, Kleinaltenkamp and Reckenfelderbäumer [25] (cf. Fig. 2.2). The authors take a marketing dominant perspective and systematize outputs for customers in two dimensions, each employing two parameters: On the one hand, the output perceived by the customer may be rather immaterial (such as additional knowledge as the result of training to operate a vertical lath) or rather material (such as a vertical lath, that has been delivered and assembled). On the other hand, processes involved to deliver customer solutions might have to be tightly integrated into the processes of customers (for example processes to design and deliver an engineered-to-order vertical lath) or can be handled rather autonomously (for example producing spare-parts and inventory management).

In this topology, customer solutions can be systematized as being co-created in relational processes of suppliers and customers and can provide tangible as well as intangible results.

2.1.3 Product-Service Systems

It has been argued, that customer solutions can be designed and delivered by the cooperation of manufacturing companies with external service providers [59] or

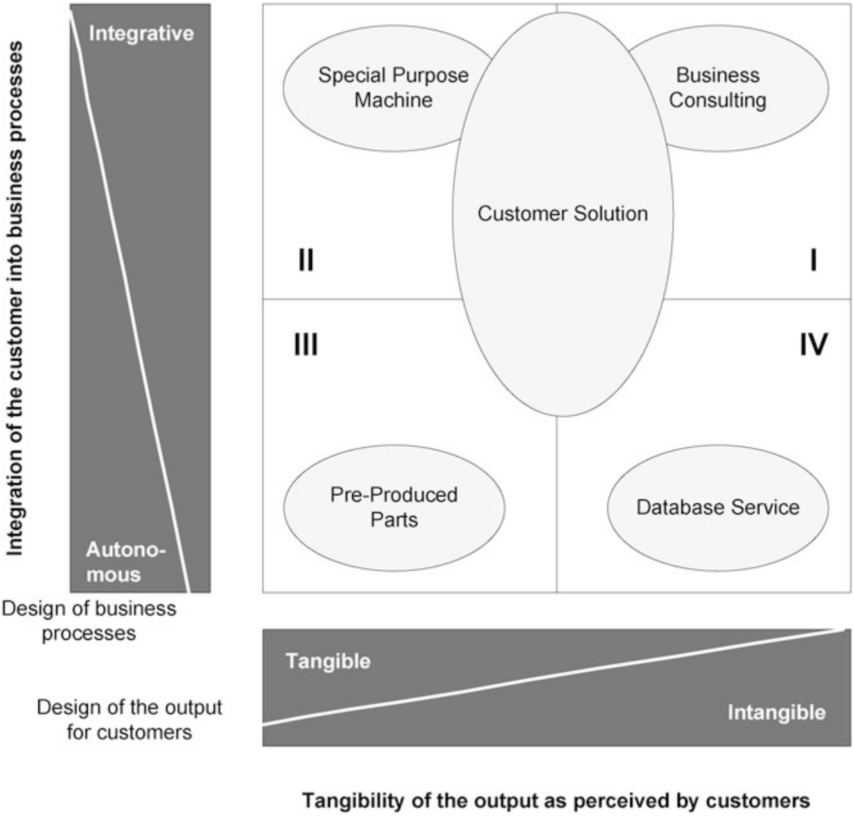

Fig. 2.2: Customer solutions as sales objects (cf. [25]).

by manufacturing companies themselves. As the integration of customers is a constitutive characteristic of service processes, customers are to be acknowledged as co-creators of value that provide a variety of inputs [63]. Providers may not offer value but only value proposition, while the creation of value is performed cooperatively with customers [85]. During this cooperation, value propositions are applied to generate value for customers (i.e., the customer solution). Customers might be consumers (B2C market), other companies (B2B market) or the public sector.

Drawing from existing definitions of Service Systems [46], we use the term Product-Service System (PSS) [5, 52, 79] as a conceptual framework for the cooperative design and delivery of customer solutions (cf. Fig. 2.3). Information flows to integrate business processes to design and deliver customer solutions (represented by arrows in Fig. 2.3) are of special interest to foster an efficient and effective design of the cooperation process.

Here, service description is a means to facilitate the integration between the several providers of a customer solution as well as to integrate the customer as co-

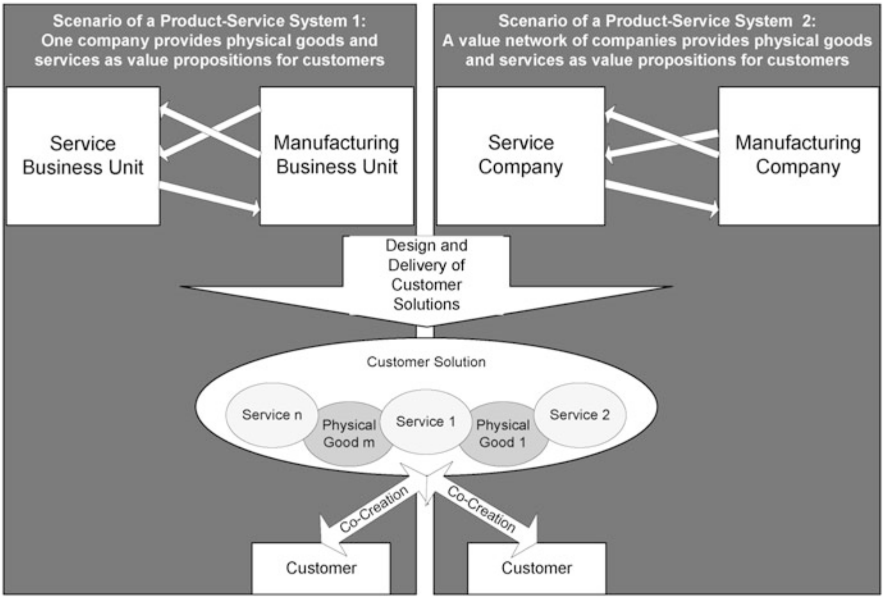

Fig. 2.3: Cooperative design, proposition and delivery of customer solutions in Product-Service Systems (PSS) (see also [5]).

creator of value into processes. Further, a purposeful digital representation of a service might allow providers for exploiting new sales channels (e.g., digital service marketplaces), and might even lead to creating and providing entirely new offers that arise from dynamically integrating value offers. Customers can be provided with enhanced functionalities in searching and finding services and composing purposeful solutions.

2.1.4 Analysis of Conceptual Modeling Approaches for Services

This work is an effort to explore the status-quo and prospects for further research of service description approaches using PSS as an example. The remainder of the chapter is organized as follows:

In the consecutive section, concepts that need to be represented in conceptual models of services from a business perspective on customer solutions are identified from four sub-disciplines of service science. These perspectives are ENGINEERING, SUPPLY CHAIN MANAGEMENT, SERVICE MARKETING, and ENVIRONMENTAL RESEARCH. We therefore review the particular needs and contributions. The identified key concepts are combined in an "evaluation sheet."

The evaluation sheet is applied in the subsequent section to discuss the current state of conceptual modeling approaches for service description in the context of

PSS. The analysis leads to the identification of further prospects for using conceptual models to describe services. The conclusion and outlook section summarizes the results and postulates directions for further research.

2.2 The Interdisciplinary Study of PSS Conceptual Modeling: Extracting Concepts

2.2.1 Conceptual Modeling and Languages

In the field of Information Systems (IS) Research, conceptual models are often used to describe, abstract from, emphasize and explain information concepts. On the one hand, conceptual models are designed with respect to unambiguously defined (i.e., specified by means of a meta-model) modeling languages. On the other hand, they should convey a degree of intuitive understanding for their users. Well-designed conceptual models enable members of an interdisciplinary project team to communicate with each other more effectively, regarding concepts such as the structural organization of a company or its business processes [19, 89].

Conceptual modeling has been argued to hold great business potential, for instance to grasp and redesign business processes in the field of business process modeling. Conceptual models used for the development of information systems may explicitly aim at addressing targeted users, senior executives, application designers, and programmers in software development processes. Thus, conceptual models can simultaneously address management issues as well as aid software and business engineering projects on an operational level.

Generally, a modeling language comprises a conceptual aspect and a representational aspect [35]. The conceptual language aspect (ortho-language) defines the meaning of the modeling constructs and relationships among them and constitutes the expressiveness of conceptual models designed with this modeling language. The representational aspect (notation) assigns representation formalisms to the specified constructs to make them easier to grasp and use for stakeholders by reducing the cognitive load imposed on human interpreters. Modeling languages determine the rules according to which conceptual models (or even reference models) can be designed. Modeling languages are usually formally described by meta-models, which represent the language concepts and their (mostly graphical) representation and can also enable advanced model operations such as specifying a dynamic semantics of models [34].

Using well-established modeling languages can accelerate the process of conceptual modeling, since modelers and users may already be familiar with the modeling language's constructs (think of modeling languages such as UML) and therefore using models might facilitate more effective communication processes. The application of well-established modeling languages may guide the modeling process and thus decreases the risk of wrong methodological decisions. Therefore, in this chapter we choose the support of current modeling languages for generating conceptual models in a PSS context as the focus of our exploration.

Conceptual models can be used to support designers in dealing with the specific requirements in a PSS context, such as (see also [7]):

- What are business processes in a PSS context like? How need the front-stage and back-stage of service systems be integrated with each other to provide customer solutions in a consistent and efficient way? How and to what extent might business processes in PSS be improved?
- Which organizational units are involved in the process of value creation of customer solutions? What is their role in the process of value creation and which components of customer solutions do they provide?
- What is the overall productivity or efficiency of a service process? Which key performance indicators should be selected to assess the performance of a service process? Against which other processes shall a service process be benchmarked in order to reason about its performance?
- How is a customer solution or an entire portfolio of customer solutions structured? Which components do these offerings comprise? What resources will be necessary to create the customer solutions? What costs will be associated with providing the customer solutions along their entire lifecycle, even if this lifecycle spans several years or even decades?
- How might individual value propositions for customers be derived from the portfolio by combining previously defined physical goods and service modules into customer solutions (i.e., bundling)? Which configuration rules do exist and how are they specified?
- How much money is a customer willing to pay for his or her configured solution? What preferences, needs, wants, and demands does a customer have? Which solutions shall providers offer to a customer from an economic point of view? Which solutions shall not be offered to a customer, because their creation is undesirable (e.g., non-profitable for the provider)?
- How much negative impact do alternative customer solutions impose on the environment? Which customer solution should be selected to minimize the ecological footprint of the value creation process?

2.2.2 Extracting Concepts from PSS Research Disciplines

The design and delivery of customer solutions is currently addressed by research in several academic disciplines [4, 86], each of which imposes its own point of view on the subject. We now provide a brief introduction of the main issues emphasized by four specific disciplines and deduce criteria as requirements to be addressed by modeling languages in a PSS context. It should be noted that these disciplines nevertheless also overlap to some extent.

ENGINEERING disciplines, such as Mechanical Engineering or Electrical Engineering, traditionally focus on engineering, constructing, and operating physical goods. In this discipline, it is often argued that a shift towards a new service economy is taking place, since manufacturing companies have strived to professionalize their service business in the recent years. To account for this shift, engineering disciplines strive to apply the common techniques of product development to the development of services also. In this respect, they deal services as units of outputs that have other characteristics than physical goods have. This point of view has been criticized as being rooted in a Goods-Dominant (G-D) logic mindset that is based on the assumption that value is created in the form of units of output rather than focusing on the relational creation of value that is favored by the Service-Dominant logic view [86].

Modeling languages for specifying physical goods and production processes have long been established in research and practice. The representation of bills of materials is one common and widespread manifestation. A bill of materials represents the model of the physical good and may break down its physical structure into components, parts or even raw materials. Each component or part is created in a definable manufacturing process, whose steps can be represented by work plans and other process models.

Creating physical goods according to formalized specifications has thus long been the focus of engineering disciplines, which has led to a considerable degree of standardization concerning ways to formally describe manufacturing processes. STEP (STandard for the Exchange of Product model data, ISO 10303-41: Fundaments of Product Description and Support; ISO 10303-42: Geometric and Topological Representation; ISO 10303-46: Visual Presentation) for example has gained particular importance in the product engineering domain [2, 57].

Additionally, a 'Service Engineering' research movement has emerged in Germany [29] in which engineering disciplines strive to apply engineering methods to the design of business services [14, 67].

Drawing from modeling bills of materials in the engineering disciplines, the service engineering discipline attempts to decompose services into sub-modules. These components can then be described by process models which closely resemble the work plans used in manufacturing. Fig. 2.4 depicts a bill of materials of a physical product (left) as well as a bill of materials of a service (right). The structural analogy of both models is striking since they both display the structure of sales objects that can be sold to customers by utilizing different hierarchical levels.

As has been shown, from an engineering point of view, representing the structure of physical goods (product engineering) and services (service engineering) and their components (*customer solutions subdivided into components*) is crucial. Based on this specification, work plans comprising activities in production processes, sequence planning, and machine capacity can be designed. Work plans are one common feature of current ERP systems. Since we will deal with processes and work plans from a Supply Chain Management (SCM) perspective in more detail, we identify three characteristics *control flow*, *capacity*, and *activities* arising from the engineering perspective.

Choosing a mass-customization approach as the underlying business strategy of the firm may enable companies to exploit economies of substitution by *reusing*

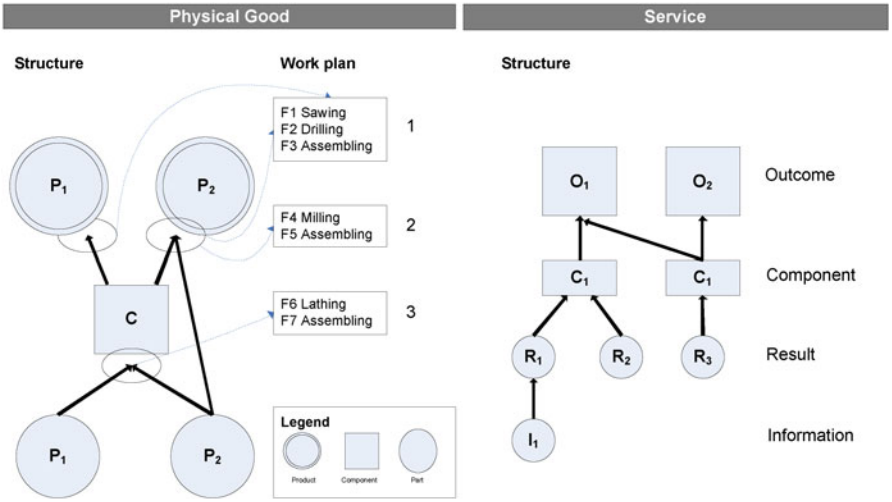

Fig. 2.4: Comparing a bill of materials for a physical good with a bill of materials for a service (cf. [42, 64]).

modules (reuse of the components as modules) [30]. Benefits to be gained from modularization include re-using existing knowledge associated with physical good and service modules, reducing performance slippage when incorporating additional modules into the bundle, reducing incorporation costs for suppliers and customers and, perhaps most importantly, making customer solutions modularly upgradeable to cope with changing customer demand (*substitution of modules*) [3, 30]. A prerequisite to assemble customer solutions from modules is to describe them in taxonomies (i.e., with is-part-of relationships) of modules as well as establishing non-hierarchical relationships (i.e., configuration rules) between modules. These might be inclusive (*configuration rules to specify inclusion (may)*) or exclusive (*configuration rules to specify exclusion (must not)*).

Components might be described by a variety of attributes (*attributes of components*), a particularly important one of which is information about the longevity of physical good or service modules (*longevity*). With respect to these attributes, services such as consulting and maintenance might differ significantly due to the size, configuration and longevity of a physical good or its components. To provide information in sufficient detail, product models have to account for a variety of lifecycle phases of the traditional product lifecycle, ranging from the start-up stage to disposal. Quality assurance is especially challenging for service processes, because inspections at the end of the service creation process can only occur after delivery to customers. Therefore, quality standards are important to be followed during any production or service process (*quality standards*). The quality of service as perceived by customers might be explained by a gap-model, as the deviation between expected and perceived service quality [54].

The discipline of SUPPLY CHAIN MANAGEMENT as an integrative discipline drawing from business, engineering, and computer science / IS points-of-view [60], emphasizes the need for managing business processes based on information modeling. The focus of study here is the actual business process that is carried out to deliver the customer solution (G-D logic point of view), or the outline how the relational process of value creation between suppliers and customers (S-D logic point of view) is or needs to be performed.

In order to document and improve the effectiveness and efficiency of the business processes in PSS, the information flows that are used to cooperatively create value are analyzed and designed. This analysis is often focused on the touch points in a service system, where value is co-created between different actors in a service system. After analyzing the interacting at these points, business processes might be redesigned and new IT artifacts might be designed to increase the overall quality or efficiency of the cooperation.

In addition, setting up service processes might be aided by drawing from past successes in disciplines such as Supply Chain Management, Materials Requirement Planning (MRP) and Enterprise Resource Planning (ERP) [21].

The discipline of Operations Management (OM) emphasizes the need for multi-disciplinary cooperation across several functional areas, such as Human Resources, Marketing or Accounting, to maximize the efficiency in providing customer solutions for customers. In OM, steps from customer analysis to product/service engineering, delivery, and disposal are not viewed in detail, but rather seen as one output of the cooperation [32].

Modeling languages for PSS have to account for these characteristics. Business processes necessary to design and deliver customer solutions include the activities to be carried out in the process (*activities*), the order in which they have to be carried out (*control flow*), materials to be procured and transported (*flow of materials*), information to be utilized (*flow of information*), and money for physical goods bought or sold to customers (*cash flow*). For services, the most important aspect to model is the work steps of the corresponding service process [65]. It has been stated, that manufacturing processes and service processes differ significantly and managerially from each other [63]. Therefore, a suitable modeling language for PSS must not model service processes in the same way as manufacturing processes, but should take distinctive characteristics of service processes such as customer integration into consideration. Because resources and inputs provided by customers are individual in each service process, modeling languages must be able to represent various customer inputs and various sequences of service processes (*resources to be introduced by customers*). Also production processes for different physical goods or their variants might be different and affect the control flow in manufacturing.

As each process uses or consumes (operand) resources in order to be carried out, process cycle times are important attributes for managing different types of manufacturing and service processes (*process cycle time*). These resources need to be reserved in order to be utilized by the process. This process can be carried out by applying techniques proposed by the discipline of production planning and control. Manufacturing as well as service processes might be subject to failure. Consequently, the failure rate should be estimated and considered for planning and scheduling the resource allocation for processes (*failure rate*).

Services processes per se are intangible, but might involve a variety of operant and operand resources during their execution. Operant resources (such as personnel, knowledge, business processes, culture, business relationships) can be seen as the fundamental source of competitive advantage [45, 85]. Operand resources are the resources acted upon when conducting service processes, such as machinery, components, parts, materials and other objects (*consumption of operand resources (economic point of view)*).

In the light of services being non-storable, suppliers have to make sure they have sufficient resources at their disposal to carry out the service process when they are requested at the 'moment of truth.' Yet on the other hand, they may want to minimize the time their resources remain idle, waiting for customer input. This optimization problem motivates a resource planning for service processes, as has been applied in manufacturing processes for years. Even if techniques such as yield management and queuing strategies have been successfully applied to manage the critical resources in service processes, a resource planning for services is still argued to lag behind resource planning in manufacturing [21].

As resources for service processes are perishable, conceptual models for business services must be able to represent resources and their capacity. Resources should be displayed in process models, such that for each function to be carried out the resources to be consumed are depicted and scheduled. During the service process, some organizational units and IT systems and applications are likely to be involved.

Because PSS might comprise different actors, such as manufacturers, service providers, and customers (as stated in Section 2.1), it is important to carry out business processes smoothly even across business units and organizations. Integrating information and processes found in the front-end and back-end of service systems has already been identified to be a considerable challenge [58, 80]. For example, to offer and deliver a managed truck fleet as a value proposition for customers, a truck manufacturer and a consulting agency have to synchronize their businesses by exchanging documents such as order and bidding documents, schedule dates, or product master data. Therefore, business processes in PSS have to be able to display, which sub-processes must be carried out by manufacturers, service providers, or customers and which activities are to be made visible to others stakeholders (see also the consecutive section).

Due to differing needs of customers and due to different resources and inputs to be introduced into the service process by customers, service processes might be carried out differently each time. Standardizing services can help to provide them more consistently across these instances.

Main points of interest from a SERVICE MARKETING PERSPECTIVE on customer solutions (notably presented by [71][84]; as well as a Journal of the Academy of Marketing Science special issue in 2008) comprise a relational view on how value is created [84, 85], determining adequate prices and business models to successfully market these value propositions [78], and integrating the customer into service processes as a co-creator of value [55, 71, 70].

The emerging research disciplines of Service Science and Service Science, Management and Engineering (SSME) respectively, focus on the design and delivery of services in Service Systems, comprising providers (or even value networks of providers) as well as customers as co-creators of value. This point of view is based on the philosophical foundation of the Service-Dominant logic (of Marketing) [86, 84]. The S-D logic view posits an alternative view on the creation of value that is based on the application of operant resources (i.e., knowledge and skills) for the benefit of another entity. Consequently, all value is created in relational processes by combining operant resources with each other. Value is assumed to be determined by the beneficiary, while a supplier cannot offer value but only value propositions. Physical goods that are exchanged between suppliers and customers are perceived to be vehicles for the application of operant resources. Therefore, all economies are perceived to be service economies, whereas the emergence of a new service economy is denied. In essence, S-D logic moves the understanding of how value is created from a focus on what is exchanged to a focus on relational value creation between suppliers and customers. Since Service Science is emerging as in interdisciplinary research discipline, it seems to go beyond the traditional boundaries of service marketing. However, we will still focus on the ‘inner core’ of service marketing here in order to derive criteria on the co-creation of value and the marketing on services as ‘offerings’ that can be advertised in the marketplace.

From a “traditional” service marketing perspective, a modeling language for services must take distinctive characteristics of services into account. The distinctive feature of service processes is the integration of customers as co-creators of value into service processes (*resources to be introduced by customers*). Therefore, it is crucial to account for the *line of visibility* and *line of interaction* towards customers [70]. Sampson and Froehle [63] emphasize, that other often cited characteristics of services (however critized by [85]) including perishability, simultaneity, intangibility, heterogeneity [27] are caused by the integration of the customer into the service process. Additionally, services cannot be produced in advance and thus are non-storable and not easily patentable. In addition to the lines usually postulated by service marketing, *relationships and lines towards stakeholders* can determine the division of labor in PSS, as processes might be outsourced to external manufacturers or service providers.

Moreover, it is difficult for customers to assess the value of a service in advance of the service process, which makes marketing and pricing services especially challenging. Therefore, offering *value propositions* for customers can be supported by adequate modeling languages. This might be achieved by providing constructs to describe, and individually configure and price (*attributes of components*) customer solutions [6]. The combination of physical objects and services is a crucial factor to be considered here. For instance, characteristics of the physical good influence which services can be offered concurrently. This means that a physical good is often the platform of which services are offered to a customer. An example would be a smart phone (i.e., a physical good) on which various services, ranging from music downloads to location-based services, can be offered. On the other hand, the services offered to a customer can also determine the properties of a physical good.

As an example, a complex apparatus might be integrated with value-added services so tightly that the services contained in the bundle determine the structure of the physical good. For instance, the general outline of a machine might be determined by the underlying business model that is used to market the solution (e.g., function-oriented as opposed to offered as-a-service).

The *marketing lifecycle* of customer solutions and its components is important to consider, because customers often take services which are in the saturation phase (such as assembly or maintenance services) for granted and might be unwilling to pay for them. In contrast, rather innovative services (such as layout planning or resource optimization services) have only recently been introduced and are more likely to be paid for by customers (*cash flow*). *Service level agreements* (SLAs) might be offered to define the quality level of physical goods and services more consistently and convince customers that the value propositions offered to them will lead to the creation of high-quality solutions that will likely be beneficial for them. Dispatching qualified personnel (*personnel allocation, qualification of personnel*), promising low *failure rates* and short *process cycle times* can be some of the elements dealt with in SLAs.

Apart from these disciplines, customer solutions from an ENVIRONMENTAL RESEARCH standpoint are seen as a means to create customer solutions with less environmental impact [51, 62, 81]. Customer solutions, if offered in performance contracting business models by specialized providers, might allow for resources to be used more efficiently due to exploiting economies of scale. Therefore, value for customers can be created in an environmentally 'sustainable' way. Authors arguing from this point-of-view tend to explicitly take environmental aspects into their definitions of customer solutions and PSS (cf. the discussion in [5]).

Modeling languages for PSS should address some basic ideas that have significance from an ecological point of view. Most importantly, the *consumption of operand resources (ecological point of view)* during production and service processes should be taken into account, because it may entail some negative environmental impact, for example due to emissions. At the end of its lifecycle (*longevity*), a physical good might be refurbished or recycled. In both cases, information about the product structure and its components is necessary (*customer solutions subdivided into components*). If modules are to be refurbished, a *substitution of modules* takes place. If modules are recycled, their material might be reused to build other physical goods (*flow of materials, attributes of components*).

A division of customer solutions into sub-components and raw materials in connection with adequate attributes can help to quantify this impact, while a modular structure with reusable components can help to spare resources due to exploiting substitution effects and economies of scale. *Legal constraints* (such as WEEE: Waste Electrical and Electronic Equipment; European Union 2003) might be important to address from an ecological standpoint, since compliance with regulations may be a binding requirement.

Table 2.1 summarizes the modeling requirements for customer solutions derived from the four perspectives. The origin of each criterion is displayed, taking into account that several criteria stem from more than one discipline.

Table 2.1: Modeling requirements of customer solutions.

Modeling language	Engineering	SCM	Marketing	Environmental
Customer Solutions subdivided into components	X			X
Reuse of the components as modules	X			
Configuration rules to specify inclusion (may)	X			
Configuration rules to specify exclusion (must not)	X			
Substituation of modules or components	X			X
Attributes of components / products	X		X	X
Longevity	X		X	X
Activities	X	X		
Control flow	X	X		
Flow of materials		X		X
Flow of information		X		
Cash flow		X	X	
Process cycle time		X	X	
Failure rate		X	X	
Capacity	X	X		
Consumption of operand resources (economic point of view)		X		
Consumption of operand resources (ecologic point of view)				X
Legal constraints				X
Value proposition for customers			X	
Marketing lifecycle			X	
Line of visibility towards customers		X	X	
Line of interaction towards customers		X	X	
Relationships / lines towards other stakeholders		X	X	
Quality standards	X			
Service level agreements			X	
IT Systems and applications		X		
Data (e.g. master data)		X		
Personnel allocation		X	X	
Qualification of personnel		X	X	
Organisational units		X	X	
Resources to be introduced by customers		X	X	

2.3 A Review of the Status-quo of PSS Conceptual Modeling and Perspectives to Service Description

2.3.1 Identifying Relevant Modeling Languages

Several modeling languages might be applied for or are particularly catered to the description of customer solutions in the context of PSS. In this section we identify a choice from the multitude of approaches has that been proposed in previous research, which is listed in Table 2.2 From this list, we have selected eight modeling languages for a more thorough analysis with the help of the previously presented requirements catalogue (grey-shaded in Table 2.2). For a more detailed overview, cf. [7]). The selected approaches are discussed below.

Table 2.2: A compilation and selection (shaded) of modeling languages.

Source	**Modeling Language**
Belz [8]	Proplan
Bitner et al. [9]; Kingman-Brundage [39]; Fließ [28]); Shostack [72]	Service Blueprinting
Black et al. [10]	ITSM-Model
Bley et al. [11]	Integrated product and process model
Bossmann [12]	CAD
Botta [13]; Steinbach et al. [75]	PDD-Approach
Congram, Epelman [16]	Structured Analysis and Design Tech-nique (SADT)
Corsten, Gössinger [17]	Framework for integrative Modeling
Dadam et al. [18]	EPAT
Dietrich, Kirn [20]	EwoMacs
Emmrich [24]	Method for systematic development of product-oriented services
Gu [31]	General Product Modeling
Hartel [33]	Collaborative Blueprinting
Scheer et al. [65]; Klein [40]	ARIS / Model-based Service System Engineering
Klein, Schreiner, Seemann [40]	K3-Method
Kunau, Loser, Herrmann [43]	SeeMe
Manavazhi [47]	Hybrid Modeling Framework
Mason [48]; Pratt [56]; Koonce and Judd [41]; IAI [36]; International Standards Organization [37]	STEP/EXPRESS-G
Maussang, Zwolinski, Brissaud [49]	Sakao's Service Representation
Rainfurth, Tegtmeyer, Lay [61]	Industrial Service Blueprinting
Schmied [66]	ProMod
Schnieder [68]; Ahrens et al. [1]	GMA 7.21
Shostack [70, 71, 72])	Molecular Model
Winkelmann [87, 88]	Coloured Petri Nets for Service Simulation

Molecular Model The Molecular Model approach rests upon the four main “ingredients” of the “marketing mix.” The approach assigns to any “market entity” a distribution strategy, a pricing strategy, advertising / promotion strategy and a hierarchical product structure. The "market entity" is the key concept of the approach. It is intended to provide a rough overview on service offerings, particularly including their composition and internal relationships.

Service Blueprinting Service Blueprinting is a family of related approaches, all of which focus on exposing the activities a service process comprises of in a chronological order. Its key analytical instrument is the "line of visibility" that separates activities. It distinguishes activities that are visible to the customer (onstage activities) from those that are not visible to the customer (backstage activities). Products, decisions and documents can be attached to the activities.

SeeMe SeeMe is also a process-centered modeling method. Apart from the representation of service processes it facilitates the assignment of organizational units, of roles, resources (e.g., documents, software programs, physical objects). Activities can be combined by connectors. The method particularly stands out by its support for assigning certain types of vagueness to roles, activities and resources.

Structured Analysis and Design Technique (SADT) SADT is grounded on the concept of Structured Analysis (SA) boxes that are intended to represent hierarchical relationships between components of a product and the idea of top-down system design. The ultimate goal of SADT is to provide a one single graphic language for blueprinting systems. In the 1980s the SADT approach was embedded into the design of the IDEF0 modeling standard. Today IDEF is part of the KBSI (Knowledge Based Systems, Inc.). Through the IDEF0 standard SADT benefits from wide adoption and extensive tool-support.

ARIS / Model-based Service System Engineering The Model-based Service System Engineering approach bases upon the ARIS modeling method. It distinguishes a product model, a process model, and a resource model to describe a service system. It extends the ARIS approach as it allows to model products from an internal perspective (product tree) as well as from a customer's perspective (product bundles). Further it introduces the concept of process module chains that shall facilitate a timely composition of service processes out of standardized components.

Colored Petri Nets for Service Simulation The approach is based on the Colored Petri Nets (CPN) technique. CPN is intended be used to model and simulate service processes. Activities are represented by transitions. Resources and events are represented by places. Properties, requirements, competencies, measures, etc. are represented by complex data types (color sets). By assigning complex expressions to the edges it is possible to estimate if an activity can be executed or which resources are required to execute it. Outgoing edges can be used to describe the output of activities in service processes.

Method for systematic development of product-oriented services The method distinguishes involved objects and activities of the service development process. It provides a modeling perspective for the (service) products that is based on the STEP approach. Further it provides reference processes that prescribe the product development process. Both are integrated in a procedure model that guides the integrated product and process development.

STEP/EXPRESS-G EXPRESS is a data modeling language that allows for the description of products structures. It is based on the standard for the exchange of product models (STEP). EXPRESS is standardized as ISO 10303-11. Behavior cannot be represented. Processes can be annotated as free text elements only. The specification comprises of 122 expressions and 318 syntax products. EXPRESS-G is a graphical notation for the EXPRESS method.

As can be inferred from this list, different modeling languages were taken into account. On the one hand, we identified general-purpose modeling languages that have been developed independently from any domain of application. Modeling languages belonging to this category are, for instance, the Event-Driven Process Chains (EPC) within the ARIS method and the Structured Analysis and Design Technique (SADT). On the other hand, we also included modeling languages that had been explicitly designed for modeling aspects in service systems, such as Service Blueprinting, the modeling techniques offered by the Model-Based Service System Engineering approach, or SeeMe. These domain-specific modeling languages provide modeling constructs that are custom-fit to the properties of services, whereas the general purpose modeling languages are generic and feature constructs that can be applied to services, however, on a more general level.

There exists a myriad of further related work, which cannot be reviewed in detail within the scope of this chapter. For example there are further approaches for standardizing the vocabulary and the processes of tendering service contracts. E.g., the Publicly Available Specification 1018 of the German Institute for Standardization [22] defines 14 stages of service provision from detecting the need of a service request to the actual fulfillment of a service contract. For each stage criteria are provided that can be used to specify a service. Each criterion is described by a definition / description of its content. The attributes are assigned either to the entire service (the header) or to a single position (position) of the service.

2.3.2 Review of PSS Modeling Languages

The features of each of the selected modeling languages were matched with the proposed modeling requirements of customer solutions. According to this exploration, the as-is capabilities of the analyzed modeling languages are depicted in Table 2.3. Results can be used to ascertain which features can already be displayed by current modeling languages, while other requirements can be shown to remain unaddressed. Gaps can be seen as potential areas for extensions with features incorporated from other modeling languages. We continue with a brief review.

Molecular Model / Service Blueprinting

Both approaches focus on a service marketing perspective. Shostack's Molecular Model allows only for roughly modeling the components of a value bundle as well

Table 2.3: As-is capabilities of modeling languages.

Modeling language	Molecular Model, Service Blueprinting	SeeMe	SADT	ARIS / Model-based Service System Engineering	Coloured Petri Nets for Service Simulation	Method for systematic devel. of product-oriented services	STEP / Express-G	Engineering	SCM	Marketing	Environmental
Customer Solutions subdivided into components	X	(X)	X	X	X	X	X	X			X
Reuse of the components as modules	X	-	X	X	X	X	X	X			
Configuration rules to specify inclusion (may)	-	-	-	-	-	-	X	X			
Configuration rules to specify exclusion (must not)	-	-	-	-	-	-	X	X			
Substituation of modules or components	-	-	-	-	-	-	X	X			X
Attributes of components / products	-	X	-	X	X	X	X	X		X	X
Longevity	-	-	-	-	(X)	X	X	X		X	X
Activities	X	X	X	X	X	X	(X)	X	X		
Control flow	X	X	X	X	X	X	(X)	X	X		
Flow of materials	-	-	-	X	(X)	(X)	-		X		X
Flow of information	-	X	X	X	-	-	-		X		
Cash flow	-	-	-	(X)	-	-	(X)		X	X	
Process cycle time	X	X	-	(X)	-	-	X		X	X	
Failure rate	(X)	-	-	(X)	X	-	X		X	X	
Capacity	-	-	-	(X)	X	X	X	X	X		
Consumption of operand resources (economic point of view)	X	X	X	(X)	X	X	X		X		
Consumption of operand resources (ecologic point of view)	-	-	-	(X)	-	X	-				X
Legal constraints	-	-	X	(X)	-	(X)	-				X
Value proposition for customers	-	-	-	-	-	-	-			X	
Marketing lifecycle	-	-	-	-	X	-	-			X	
Line of visibility towards customers	X	-	-	X	-	-	-		X	X	
Line of interaction towards customers	X	-	-	X	-	X	-		X	X	
Relationships / lines towards other stakeholders	(X)	-	(X)	X	-	(X)	-		X	X	
Quality standards	-	-	X	-	X	X	(X)	X			
Service level agreements	-	-	-	X	-	-	-			X	
IT Systems and applications	-	X	X	X	X	-	(X)		X		
Data (e.g. master data)	(X)	X	-	X	-	-	X		X		
Personnel allocation	(X)	X	X	X	X	X	-		X	X	
Qualifikation of personnel	-	(X)	X	-	-	X	(X)		X	X	
Organisational units	-	X	X	X	X	X	-		X	X	
Resources to be introduced by customers	X	(X)	(X)	X	X	X	-		X	X	

as related strategies for distribution, price and communication. Processes, resources and the interaction with stakeholders are not (explicitly) considered. The analyzed Service Blueprinting approaches allow for a more detailed modeling of the service processes' activities. These activities can be assigned to roles. Products and materials are mainly not in the focus — only Shostack's approach allows for representing them as specific objects. Resources and legal constraints are not considered as well as required qualification of personnel or quality attributes. Shostack's approach further provides attributes for benchmarking and exception handling of processes. Kleinaltenkamp highlights interaction aspects within the service company. Bitner et al. focus on the customer integration.

SeeMe

The SeeMe approach is also centered on the process view. It follows a modularization strategy that allows bundling activities that can be reused in different service modules. Physical products (and their structure) can also be represented. A specific representation of the service (product) is not supported.

SADT

SADT is a ubiquitous modeling approach. Accordingly, SADT models tend to suffer from complexity. Several models of the same objects would be required, e.g., in order to represent the resource flow and to facilitate a knowledge management or physical component perspective.

ARIS / Model-based Service System Engineering

Model-based Service System Engineering is an ARIS approach that is tailored to fit services. It provides constructs to meet a variety of our requirements. Particularly the service product description and the representation of the interfaces between products and services as well as the degree of integration could be addressed more explicitly.

Coloured Petri Nets for Service Simulation (CPN)

This method strives to facilitate the simulation of service processes. Obviously the method focusses on a process view on service systems thus it does not comprise of specific concepts for representing static structures. Service products could be integrated into the models as complex data types only. Also resource-based aspect of the service system can be described by such data types. Dedicated software support is available that eases reuse of model components. However, modifications and extensions of the modeling technique, versioning of models, and maintaining model variants are not supported.

Method for systematic development of product-oriented services

The approach has a manufacturing background. Accordingly it strives to suit engineering disciplines at first. While it emphasized a modular structure of service products, it disregards the relational processes of service value creation. Also, required IT systems and data objects are neglected.

STEP / EXPRESS-G

STEP and EXPRESS-G focus on representing static product structures (product definition, product representation, product presentation). However, modeling of processes and resources are not supported. Projects for further developing the method strive for filling that gap.

Although some modeling languages provide constructs for a variety of requirements, none of the modeling languages is capable of accounting for all the proposed modeling requirements. E.g., interfaces between physical goods and services as well as the configuration and offering of customer solutions are seldom addressed. Thus, in conceptual models derived by using these modeling languages it remains unclear, how intense the integration of physical goods and services is and how cooperation scenarios for offering and delivering customer solutions should be designed.

In addition to general deficiencies, the investigated modeling languages are unlikely to display features originating from other research areas than the one from which the modeling language emerged. We make the following observations in this regard:

- Modeling languages not originating from an engineering background usually lack a representation of a bill-of-materials and other product-related data, such as lifecycle information (referring to maintenance cycles) on a component level of detail. This information would nevertheless be helpful to guide service processes, for example by identifying components and parts that require service activities along their lifecycle.
- Modeling languages not originating from an SCM background tend not to display the IT systems as well as business units involved in service and manufacturing processes. As service processes tend to be labor intensive and require information to be delivered at the correct moment (i.e., the 'moment of truth'), providing these constructs seems to hold significant potential to assign resources and information on time.
- Modeling languages not stemming from a service marketing point-of-view are unlikely to address the type and intensity of customer integration, e.g., by displaying the line of interaction and line of visibility towards customers. Acknowledging customers as important members of PSS and as co-creators of value implies accounting for their information and resource input during the service processes. Hence, customers should be representable by conceptual models in PSS.
- Environmental aspects remain largely unaddressed by all the evaluated modeling languages. We could not identify any formal modeling language specially designed for this purpose.

2.4 Discussion, Limitation and Outlook

In this chapter we have introduced the creation and provision of customer solutions as a chance and challenge to manufacturing companies. PSS here serves as an example for the increasing importance of service from an economical as well as a managerial perspective. Designing and delivering customer solutions is a complex undertaking since it requires the cooperation of various business units, companies and customers in PSS. We exhibited that the description of customer-specific solutions is a crucial task in these efforts.

Conceptual modeling techniques can be used to better cope with this challenge. Conceptual modeling benefits from sound modeling languages, which provide constructs for formally representing business-related aspects of a service description. To analyze the status-quo of modeling languages for PSS, we derived an evaluation sheet drawing from some viewpoints emphasized by four relevant academic disciplines involved in service research. We applied the proposed evaluation sheet on a selection of eight modeling languages in the area of PSS, originating from these different research areas. We found that adequate support of conceptual modeling by modeling languages for PSS is lacking, as the modeling languages under consideration tended not to adopt an interdisciplinary point of view, often restricting themselves to the research discipline from which they originated. In the light of the need to comprehensively describe services from several points of view (which is a prerequisite to identify and invoke services on electronic service marketplaces) this underlines the need of developing more advanced conceptual modeling support for the description of services.

The approach taken in this chapter is subject to some limitations. First, the criteria developed for analyzing the expressive power of conceptual modeling languages cannot be exhaustive, but remain limited to the perspectives we have applied to identify them. In future work, a more thorough catalogue of evaluation criteria might be developed that comprises the foci of still other research disciplines involved with research in Service Science. Second, additional criteria originating from the four discussed research streams might be added to the list. Another limitation is the selection of the conceptual modeling languages themselves. Although we included all conceptual modeling languages that we came across into the analysis, still others likely exist and need to be analyzed with the proposed criteria to create a more comprehensive overview.

Therefore, the concepts presented in this chapter are meant to act as a starting point to develop a more advanced support of service description and with regard to customer PSS-offered customer solutions in particular. With the results we strive to propose directions for extensions to be made to existing modeling languages. This might help to encourage further interdisciplinary research activities carried out in the currently emerging disciplines of Service Science and Service Science Management and Engineering (SSME).

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