Reference Models and Modeling Languages for Product-Service Systems – Status-Quo and Perspectives for Further Research

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Abstract

Being confronted with decreasing margins and a rising customer demand for integrated solutions, manufacturing companies integrate complementary services into their portfolio.

Offering product-service packages (consisting of products and services) demands for setting up integrated product-service systems, which incorporate the coordinated design and provision of products and services. Conceptual Modeling is an established approach to support such efforts.

This paper evaluates the current support of reference models and modeling languages for setting up conceptual models in the area of product-service systems. Consecutively, some perspectives are presented to induce further research in this field.

1. Introduction

Commercial customers as well as consumers increasingly demand complex solutions instead of solitary physical goods or stand-alone services. As some underlying causes, the trend for convenience (consumers) and the trend to concentrate on core competencies (commercial customers) can be seen.

While the provision of technology is more and more seen to become ‘commodity’ that can be rather equally provided by different companies, services are seen as a means to allow for more differentiated offerings and contribute to superior value creation.

Accordingly, manufacturing companies increasingly drive their business by surrounding products with services[27]. Even in 2000, product-related services accounted for 18.5% of total turnover in German Mechanical Engineering and 22.5% in the Electrical Engineering sector[62]. In the U.S., leading edge manufacturing companies already drive 50% of their revenues and 60% of their margins from offering services[1].

Services may correspond to different lifecycle stages of the product, such as start-up, operation or disposal stage (cf. Figure 1). Services in the start-up stage may e.g. constitute pre-sales services like consulting and layout planning. During the operation stage, service activities are mainly conducted to uphold the operability of the physical product (e.g. a vertical lath); but services may as well include training employees or providing skilled personnel during operation. Referring to the disposal stage, the product might be disassembled, recycled, or sold again to another customer.

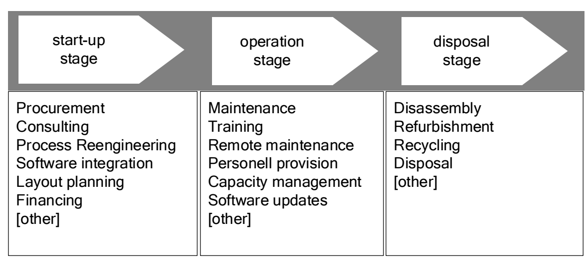

Figure 1. Services surrounding the physical product during its lifecycle-stages (excerpt)

Benefits to be gained from combining products and services are manifold[48], such as crafting long-term client-consultant relationship in engineering, increasing flexibility of use for products, generating higher performance of the product[27] or enabling new business models. Product-service packages can be offered in cooperation of manufacturing companies with external service providers[47] or by the manufacturing company itself. We use the term product-service system[39] in both cases to describe the cooperation aimed at designing and providing product-service packages (cf. Figure 2). The interfaces of the cooperating business units in manufacturing and service are of special interest to foster an efficient and effective design of the cooperation[48]. Moreover, there should be an unambiguous understanding on how to carry out the business processes cooperatively.

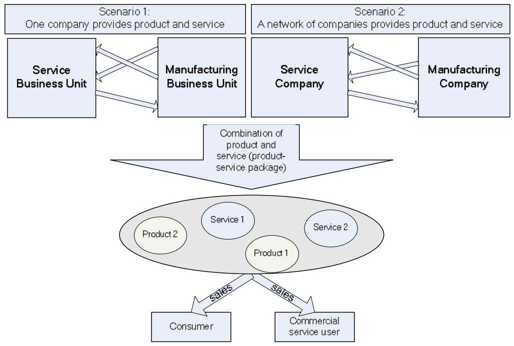

Figure 2. Configurations of product-service systems

In order to develop effective and efficient product-service systems, business requirements need to be identified and modeled as conceptual models. Conceptual models support the integration of organizations and their processes and IT applications by adhering business requirements. Conceptual models should have a degree of formality in order to clearly specify the business and information systems; yet, a degree of intuitive understanding for its users must be conveyed. Thus, conceptual models enable members of an interdisciplinary project team to communicate with each other more clearly and unambiguously. Conceptual models explicitly allow the inclusion of targeted users, management, application designers, and programmers within the development process of an information system. Therefore, they address management support and user involvement in understanding and designing the business and IT functions.

The aim of this paper is to investigate and advance the status quo of the methodological support for conceptual modeling to design and operate product-service systems. In Section 2 we identify and select the methods for conceptual modeling of product-service systems and reference models for product-service systems as the two dimensions of our analysis.

Section 3 presents a status-quo of reference models found in manufacturing and service. As currently little domain knowledge in the context of product-service systems is made available, the usefulness of providing integrating reference models is presented by introducing a real-life cooperation scenario of manufacturing and service.

In Section 4, some existing modeling languages are presented and evaluated according to the requirements of product-service systems. To overcome deficiencies of existing methods an integration approach is postulated.
The paper concludes by summarizing the results and proposing directions for further research in Section 5.

2. Support for conceptual modeling of product-service systems

Conceptual modeling can be done to represent the specific business requirements of an existing or planned product-service system. In the previous case conceptual models can serve as as-is-models, in the latter case as to-be-models. The process of modeling is a time and cost consuming effort. Therefore, it is reasonable to use existing reference models as a starting-point to develop specific conceptual models of existing or planned product-service systems.

Reference models provide best-practice processes, which can be adapted to aid companies in designing and operating their business. Therefore, reference models can act as quickly adaptable basic solutions for implementing adequate business processes and speed up the design of organizational concepts and information systems. Additionally, they facilitate the transfer of knowledge into companies (e.g. by proposing common-practice business processes). Therefore, adapting reference solutions can lower the risk for companies to adapt unsuccessful and non-verified concepts.

The benefits of reference models for the process of conceptual modeling motivate the request to design reference models for product-service-systems. Therefore, the support provided by reference models is presented as the first aspect of our investigation (cf. Figure 3).

Another approach to facilitate a successful development of specific conceptual models is to provide adequate modeling languages. Modeling languages describe how conceptual models should be developed. The modeling language can be described by meta models, which can be differentiated by their purpose. Of particular importance are meta models which represent the language concepts of the modeling language and meta models which guide the process of modeling. Meta modeling is orthogonal to reference modeling, because a meta model determines the structure of the model and guides the modeling process, while reference models provides content which can be reused. In some cases the modeling language for reference models and specific conceptual models can be even the same.

Just like reference models, using established modeling languages can raise the efficiency of the modeling process. Moreover, using sound meta models can enhance the expressiveness of the conceptual model, because the conceptual model is developed according to formalized requirements. The application of an established modeling language decreases the risk of wrong methodological decisions. Therefore, we choose the support of product-service system modeling by modeling languages as the second aspect of our exploration (cf. Figure 3).

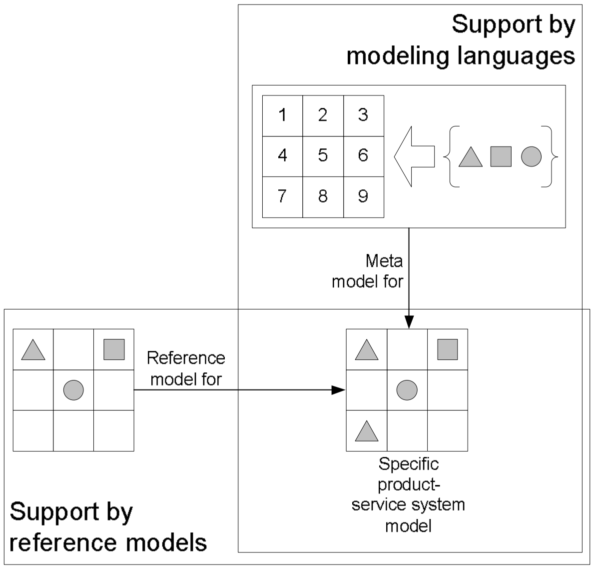

Figure 3. Support of conceptual modeling by reference models and modeling languages[21]

3. Reference models for product-service systems

3.1 Status-quo

To assess the current reference model support for product-service systems, we have analyzed existing reference models in the manufacturing and service sector. As a starting point, we examined two catalogues for reference models[1]. This compilation was extended by a literature survey, which we carried out by searching several journals[2] and conference proceedings[3]. Furthermore, we added some reference models found in standards of the International (ISO) and German Standardization Organizations (DIN) to this dataset. Thus, a status-quo of reference modeling in the area of product-service systems was derived. We categorized the reference models (Figure 3) according to their main focus (M=Manufacturing, S=Service, M/S=Manufacturing and Service).

In the area of manufacturing, 13 reference models could be identified. These models reach from domain-unspecific models (SCOR, Y-CIM) to quite specialized models (e.g. for Conveying Systems or Inventory Management). As processes found in the area of manufacturing tend to be comparable, reference models can be applied to guide manufacturing processes to a great extend.
In the service sector, we have identified 15 reference models. These reference models substantially differ among each other, as service processes are carried out differently to satisfy the requirements of different customers. Even more so, services also differ when compared to other services. Thus, e.g. banking services differ from IT infrastructure services in terms of complexity and in terms of the stakeholders involved in the service process.

Considering the area of product-service systems, there is little methodological support for manufacturers and service providers to interact upon (cf. Table 1). Analyzing the scope of the compiled reference models, only three reference models explicitly cover aspects from both the manufacturing and service sector. When compared to the more general view of reference models found in manufacturing or service, these models contemplate quite specialized areas, such as Quality Assurance or Facility Management. Therefore, the current support lacks the explanatory power to sufficiently guide manufacturing and service in understanding, engineering and operating product-service systems, which may have to cover several lifecycle phases of the product (e.g. implementation, operation, and disposal).

Table 1. A classification of existing reference models[16]

Reference model	Proposed by	Domain
Aachener PPS Model	Luczak (1998)	M
DCOR	Supply Chain Council (2006)	M
Online-Content-Syndication Model	Pankratz, Benlian (2004)	M
Prozessrahmenwerk Siemens AG	Rohloff (2002)	M
Electronic tender in procurement	Buchwalter (2001)	M
Conveying systems	Kluger (1999)	M
PPS, Cost culculation, personnel	Ohlendorf (1998)	M
Inventory Management	Tzouvaras (2003)	M
Rosetta Net (supply chain management)	RosettaNet (2007)	M
SAP (various industry solutions)	Keller (1999b)	M
SCOR (Supply Chain Management)	Supply Chain Council (2007)	M
Y-CIM Model	Scheer (1990, 1994)	M
ECO Integral	Krcmar (2002)	S
IBM Insurance Application Architecture	Huschens, Rumpold-Preining (2005)	S
ITIL	Hochstein, Hunziker (2003)	S
Banking Online Information System	Bauer (1998)	
Service Data Management for IT Services	Böhmann et al. (2004)	S
After sales services	Dangelmeier et al. (2004)	S
Chain Store for Banking	Gerber, Mai (2002)	S
Technical Facility Management	Neumann (2003)	S
IT-Service Information System	Probst (2003)	S
Contact Management Insurance Companies	Rottwinkel (2004)	S
Life Assurance	Rüffer (1999)	S
Controlling	Schlagheck (2000)	S
SIZ Banking Data Model	Kittlaus, Krahl (2005); Eisenreich (2002);	S
	Krebs (2001)	S
Telecommunication	Keller (1999a)	
PAS-1047 (Foult Repair)	DIN (Deutsches Institut für Normung e.V.)	S
	(2005)	S
Y-CIM Model for Services	Hermann, Klein, The (2006)	
Insurance	Gesamtverband der Deutschen	S
	Versicherungswirtschaft (2001)	S
Quality Information Systems	Hoffmann (1999)	M/S
PPS, Personell, Facility Management	Mertens (2001)	M/S
Quality Information Systems	Schildheuer (1998)	M/S

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1 www.referenzmodelle.de, provided by the University of Münster and http://rmk.iwi.uni-sb.de/, provided by the University of Saarbrücken. Some of these reference models were compiled and analyzed in a survey by Fettke; Loos 2004 [16].

2 in detail: HMD-Praxis der Wirtschaftsinformatik, Informatik Spektrum, IM Information Management & Consulting, Wirtschaftsinformatik.

3 in detail: Modellierung, Modellierung betrieblicher Informationssysteme, Referenzmodellierung, Wirtschaftsinformatik (biannual conference, searched until 2005). By searching the journals and conference proceedings, the compilation derived by Fettke/Loos [16] [15] was extended to comprise the years 2004-2006.

3.2 Perspective: Integrating reference models for product-service systems

An integration of reference models found in manufacturing and service seems beneficial to more thoroughly guide cooperation for designing and operating product-service systems.

Integrating reference models can be accomplished in several ways[50]: By aggregating reference models, only the compatible parts of the models are put together to form a new reference model, which reduces the overall complexity due to regarding the intersection; by joining reference models, only parts of the models are connected to each other. In the latter case, on the one hand redundancies may occur due to overlapping information. On the other hand, the effort needed for the integration is lower, because an ex-post integration of existing models allows for existing elements to be reused. Furthermore, joining reference models allows for new functions and data objects to be inserted into the new reference model, which is a critical requirement to represent e.g. special information flows in product-service systems.

Benefits to be gained from joining reference models include an improved actuality of the information represented by the model and a managed integrity of the overall model. In the area of product-service systems, the overall design and execution of manufacturing processes and service processes can be managed more consistently and with improved timeliness. Of particular interest for designing efficient cooperation is to display the interfaces of manufacturing and service business units when providing integrated solutions, e.g. to design well-integrated IT support for corresponding business processes.

Example: Integrating reference models for product-service systems

Providing customers with an optimized truck fleet management can be considered as an example of a product-service package. The packaged solution comprises trucks as physical objects and consulting/ optimization services. Ranging from production to re-selling or disposing the trucks, the services surround the product along its entire lifecycle.

Several organizational settings are possible for providing an optimized truck fleet: One manufacturing company might manufacture the trucks as well as provide the consulting services. On the other hand, trucks might be offered by a manufacturing company, whereas the services are provided by an external consulting agency. In the following example, we present the latter case.

Offering an optimized truck fleet to the customer as a packaged solution, the companies need to exchange information to make sure the product and service components fit together, such as information related to the physical attributes of the vehicles or data gained during the consulting process. In terms of reference models, the activities to be carried out can be systematized by the Y-CIM (Computer Integrated Manufacturing) model (truck manufacturer) and an adapted version of the Service-Y [22] (consulting agency).

Integrating the reference models provides a framework for the cooperation in product-service systems (see Figure 4 for an excerpt) and systematizes interfaces and information flows in both directions. In particular, the following information flows can be identified:

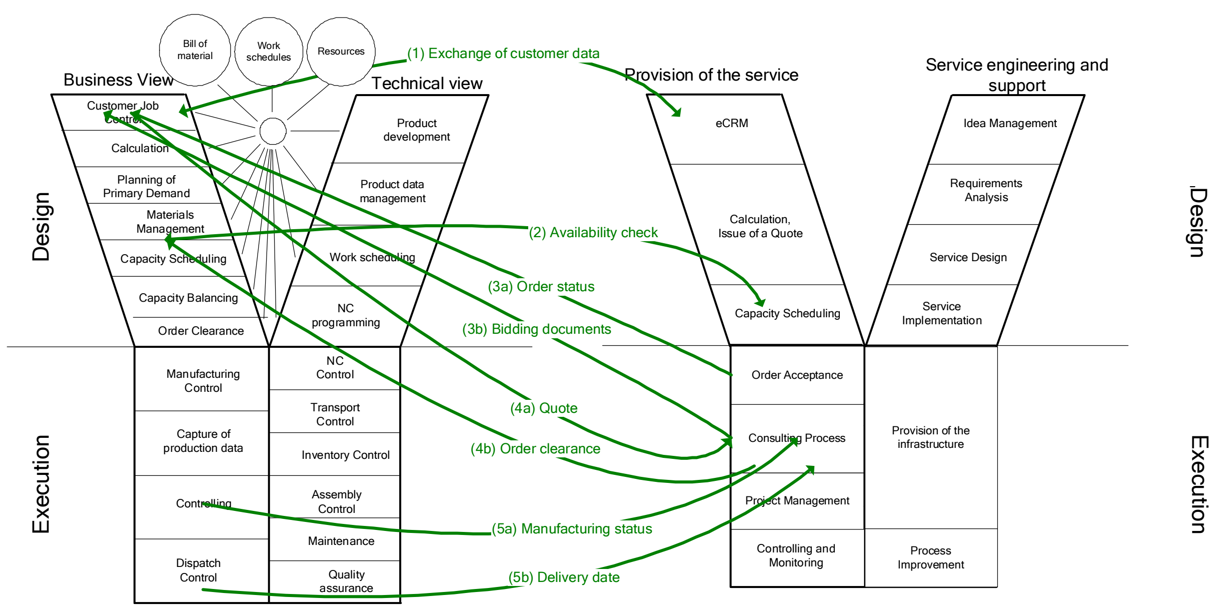

Figure 4. Reference model integration for truck fleet management (excerpt)

An exchange of customer data is beneficial for a joined customer relationship management. Thus, customers potentially interested in buying an optimized truck fleet can be identified more easily (1). After the consulting agency has analyzed the existing truck fleet of the customer, new vehicles might be bought. Therefore, the consulting agency ascertains the availability of trucks at the manufacturing company (2). In case the manufacturer is capable to deliver the trucks, the consulting agency updates the order status in the manufacturers Production Planning and Scheduling system (3a) and issues detailed bidding documents (3b). In turn, the truck manufacturer issues a quote (4a), that is accepted by the consulting agency. Consecutively, order clearance is provided (4b). During the manufacturing process, the truck manufacturer provides updates related to the current status of the production (5a) and the scheduled delivery date (5b).

4. Modeling languages for product-service systems

4.1 Status-quo

To soundly design and execute the business processes in product-service systems, they first have to be modeled in detail. Whereas reference models provide general guidelines on how to conduct business processes, the execution of the business processes itself is conceptualized in process models. To be useful in the context of product-service systems, these process models have to account for the modeling needs of products and services. Thus, when compiling and evaluating the status-quo of existing modeling languages for product-service systems, modeling requirements of both products and services have to be taken into account.

Characteristics of products and the manufacturing process

Manufacturing is more and more carried out in cooperation of various producers due to the strategy to focus on core competencies. Therefore, it is crucial to keep to detailed work-plans, time schedules and capacity schedules.

Automatic shortest path selection algorithms allow for raised efficiency with respect to material handling in a plant[14].

A product-structure might comprise several hierarchical layers of components, parts and materials. Therefore, for smooth production processes, it is imperative to have well-documented product specifications and bills of materials at hand. Important data on each level of granularity include product-ID, planning type, validity period, costs, sourcing type, mean cycle time and mechanical drawings.

Characteristics of services

A modeling language for services must be designed according to constituting characteristics of services. Properties often stated in Service Management literature are[18]:

Customer participation: Services require an integration of the customer, because customers play an active role during the service process.

Simultaneity: Services are created and instantly consumed by the customer. One consequence is that services are non-storable. Thus, companies have to make sure they have sufficient resources at their disposal to carry out the service process when it is requested by the customer. Quality assurance is especially difficult, because there can be no inspection at the end of the creation process due to simultaneous consumption.

Perishability: Due to their immaterial character, services cannot be produced in advance. Therefore, service capacity must be managed, because it is inescapably lost if unused.

Intangibility: Services as such are not patentable. Furthermore, it is difficult for customers to assess the value of the service in advance of the service process. Hence, the reputation of the service company and the expected service quality is likely to guide the customer when choosing vendors.

Heterogeneity: Due to differing needs of customers, the service process is carried out differently each time. Standardization of services can help to provide services more consistently. Dispatching capable employees is a crucial prerequisite for providing services in sufficient quality.

Modeling requirements for product-service systems

Augmenting the modeling requirements of products and services with additional requirements of product-service packages, we derived an evaluation sheet for modeling languages. Criteria include modeling the service process, scheduling resources during the service process, displaying characteristics of the product, and providing information about the integration of products and services.

From a service point of view, the most important aspect to model is the corresponding business process[58] due to the lack of a physical object (intangibility). From a top-level perspective, modeling languages have to represent various sequences of the underlying business process (heterogeneity). It is crucial to account for the line of visibility and the line of interaction towards the customer (customer participation). Service descriptions can describe a potential in advance of the service process as well as a special instance of the process for a certain customer. Modeling languages may depict legal constraints.

On the other hand, during the service process, models must be able to represent production factors (employees, apparatus et cetera) and their capacity (perishability). Resources (material, employees et cetera) are needed to carry out the functions of the service process. They should be displayed in process models, such that for each function to be carried out the correct resources are depicted. If possible, skills of the employees shall be taken into consideration, because services are highly subject to skills of the companies' employees (heterogeneity). During the service process, organizational units and IT systems are likely to be involved.

To account for the characteristics of the product, modeling languages have to account for product modeling requirements. Product models seem particularly valuable when modeling business processes for product-service systems, because services (such as logistics, maintenance or consulting services) are dependent on the physical components and characteristics of the product to a great extend. Thus, consulting and maintenance differs according to e.g. size, configuration and longevity of a product. To provide information in sufficient detail, product models have to account for a variety of lifecycle phases of the product, ranging from the start-up stage to disposal.

Eventually, in product-service packages, the combination of physical objects and services is crucial. Complex apparatus might be integrated with services more broadly than rather low-end devices. Furthermore, services demand for different types of combination. As a consequence, modeling languages should be able to display the type and intensity of the integration of products and services. Stakeholders (e.g. the customer or an external service provider) may be involved in the creation of the product-service system. In addition to that, services might relate to objects that cannot be categorized as material objects, but rather imply an indirect evidence[61] of them (e.g. a check book, representing a bank account).

Based on the modeling requirements of products and services, we have analyzed existing modeling languages due to their adequacy to describe product-service systems and the underlying business processes. Stemming from different research areas, the coverage of the criteria also is different. While some approaches stem from a marketing perspective on products and services (molecular model, service blueprinting), other originate from the manufacturing perspective (Emmrich, poDLE, Business Integration Model). Still others have been adapted from the Information Systems area (ARIS, Petri Nets).

The result of the evaluation is depicted in Figure 5. No modeling language adheres all the proposed modeling requirements of product-service systems. In particular, interfaces between products and services and the degree of integration are seldom addressed. Thus, it remains unclear, how intense the integration of product and service is and how cooperation scenarios should be designed when providing product-service packages.

Furthermore, many modeling languages lack a representation of a bill of materials and other product-related data, such as lifecycle-related information (e.g. maintenance cycles) about the components of a product. This information would be helpful to identify components and parts involved in service activities, according to predetermined lifecycle stages.

Related to providing the service process itself, IT systems as well as organizational business units involved are seldom displayed in current modeling languages. As service processes are labor intensive and require information to be delivered at the correct moment, providing these constructs seems to hold some significant potential.

Referring to customer integration, the line of interaction and line of visibility cannot be displayed in most modeling languages. A broader integration of the customer into service modeling seems beneficial, because no service is carried out in exactly the same way twice (due to the involvement of the external factor), but is highly subject to the involvement of the customer.

Although existing modeling languages can also be applied in the area of product-service systems, a lack of sufficient methods for a formalized design and operation of product-service systems and the related service processes is identified.

4.2 Perspective: Integrating modeling languages for product-service systems

To provide sound methodological support, modeling languages for product-service systems should include attributes of the product, the service process, resources used during the service process and information about the integration of product and service.

Thus, e.g. it can be ascertained, which parts of a product require services processes in a specific lifecycle-phase, who should conduct the service process and what resources are to be dispatched during the service process. In this way, a holistic support of the domain would be provided for.

Facing a lack of sufficient modeling languages for product-service systems, an integration of existing modeling languages seems beneficial to reach a sound coverage of these dimensions. Integration can be achieved in several ways, one of which is an integration of the modeling languages' meta models[25].

As meta models of different modeling languages often exist in different notation, a first step towards integration is to specify meta models in one modeling language. Consecutively, a comparison of the meta models can show compatible starting-points for integration. Eventually, a new meta model is created, incorporating facets of both meta models. This new meta model can be used to instantiate conceptual models that are designed due to these specifications.

Modeling language	Molecular model (Shostack 1977)	Service Blueprinting (Shostack 1982)	ARIS (Scheer, Grieble, Klein 2006)	Emmrich 2005	poDLE (Dangelmaier, Hamoudia 2002)	Business Integration Model (Luczak 1991)	Service Improvement Programme (Andrade, Clausing 1997)	Coloured Petri Nets (Winkelmann, Luczak 2006)	Category
Business process specification		X	X	X	X	(X)	X	X	Service
Alternative sequences and cycles		X	X	X	X	(X)	X	X	
Line of visibility		X							
Line of interaction		X				X			
Distinction of service potential and service process		X	(X)	X		X			
Legal constraints (service)			(X)		X				
Skills of personnel and personnel allocation		X		X	X	(X)	X		Resources and Efficiency
Execution time and allowed deviation time		X			X			X	
Crucial production factors and capacity constraints			X	X	X	(X)		X	
IT systems and data objects			X						
Organizational units, relatiopnships and hierarchies			X	X					
Hierarchical product-structure (e.g. components, parts)		(X)	X	X					Product
Explicit service needs and characteristics of the product									
Product lifecycle				X		(X)			
Legal constraints (product)			(X)						
Quality standards			X	X	X				
Type of combination (product and service)	X	X		X		X			Product-service combination
Intensity of the combination	X	X							
Peripheral and essential evidence	X	X							
Relationships towards stakeholders		(X)	X	X	X	X		X	

Figure 5. As-is capabilities of modeling languages in the light of the requirements of product-service systems

Meta models can support the creation of conceptual models in two ways. Language oriented meta models provide information about the structure of a model. They can be constructed by enhancing the table of symbols of the meta model with specifications about the arrangement of the symbols. In contrast, process-oriented meta models guide the design process of conceptual models by providing step-by-step assistance during the modeling process.

Example: Integrating modeling languages for product-service systems

As an example for the meta model based integration of modeling methods we combine the Event-Driven Process Chain (EPC) and the Service Blueprinting approach by integrating their meta models.

One of the most important goals for service providers is to ensure an appropriate customer integration in service processes[45]. Recommendations for structuring provider activities that focus on customer interaction have been discussed exhaustively in marketing literature[61][17]. Amongst these approaches, Service Blueprinting is characterized by a particularly high degree of differentiation[17]. This approach differentiates provider activities at different levels confined by ‘lines’. For example the ‘line of interaction’ separates customer activities from provider activities and the ‘line of visibility’ separates customer-perceivable activities (‘onstage activities’) from customer-imperceptible activities (‘backstage activities’). Being specialized on the analysis of customer integration, Service Blueprinting has advantages and drawbacks when compared to the ARIS framework[57].

EPC is one of the central modeling technique in the ARIS framework. EPCs are bipartite, directed graphs which comprise three basic elements (functions, events and logical connectors) indicating the control flow[57] of a business process. Various extensions of the EPC can be found in specific domains such as knowledge and document management, e-Government, or risk management[41][42]. From the perspective of product-service systems, specific extensions with regard to the analysis and specification of customer activities should additionally be made.

The composition of the constructs of the languages of Service Blueprinting and EPC can be modelled in a meta model. Figure 6 depicts an excerpt of the underlying meta model of the EPC as entity relationship model. Areas of activity, which are divided by the lines of the Service Blueprinting approach, extend the conceptual aspects of the EPC for a proper analysis of customer activities. For the application of the extension, corresponding notation constructs are needed. We propose to illustrate the areas by means of the swimlane notation which leads to a segmentation of business processes. Alternative notations could also use different colours for the various functions, each colour representing a specific area of activity.
By differing activity areas, the combined modeling method supports analysis like ‘Which aspects of support activities should be made visible to customers?’. These issue is especially important when design the integration of the customer in the service processes as specified in a product-service-system.

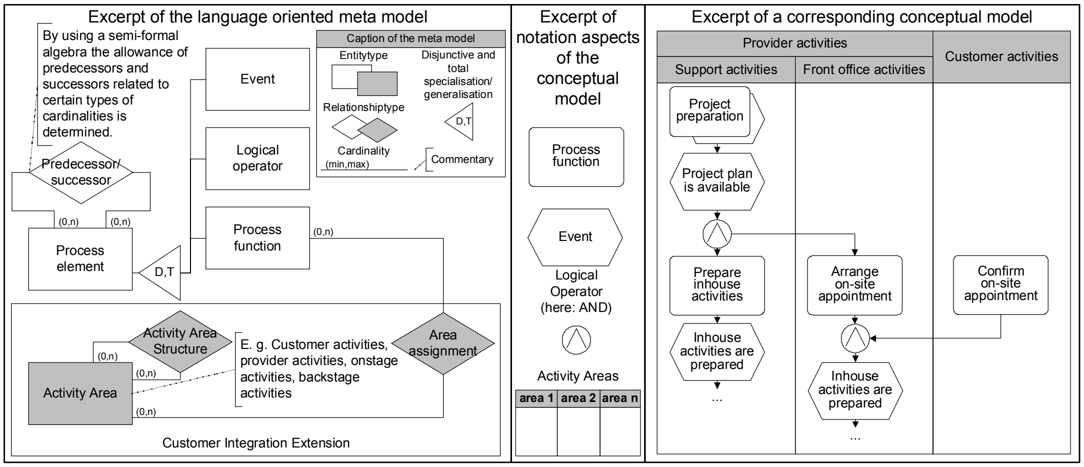

Figure 6. Extending EPCs to display the line of interaction by integrating meta models

5. Summary and outlook

In this paper we demonstrated that the creation and provision of product-service packages is a crucial issue in today's economy. Even so, engineering product-service systems with conceptual models is lacking sound methodological support. In this paper, we provided an overview of the status quo and presented perspectives for research in two dimensions:

(1) Cooperation of manufacturers and service providers can be conceptualized by reference models. Facing a lack of reference models suitable for both the areas we propose joining suitable reference models found in the manufacturing and the service sector. This integration is accomplished by identifying interfaces and information flows among manufacturing and service business units.

(2) Current modeling techniques cannot display processes used in product-service systems in sufficient detail, because they lack an integration of the manufacturing and the service perspective. Therefore, we briefly introduced some characteristics for a suitable domain specific modeling language, which can be constructed by integrating meta-models of modeling languages.

The development of methods and reference models as IS artifacts is a matter of the design science paradigm[23]. Therefore, the concepts presented in this paper act as a starting point to develop a tighter methodological support for conceptual models, that will be evaluated more thoroughly in a variety of real-life product-service systems.

6. Acknowledgements

This paper was written within the context of the research projects FlexNet and ServPay, funded by the Federal Ministry of Education and Research (BMBF), promotion signs 01FD0629 and 02PG1010.

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