Inf Syst E-Bus Manage (2014) 12:337–365
DOI 10.1007/s10257-013-0219-y

ORIGINAL ARTICLE

On the ontological expressiveness of conceptual modeling grammars for service productivity management

Jörg Becker · Daniel Beverungen · Ralf Knackstedt · Hans Peter Rauer · Daniel Sigge

Received: 11 April 2012 / Revised: 30 December 2012 / Accepted: 11 March 2013 /
Published online: 2 April 2013

Abstract Conceptualizing, analyzing, and optimizing service productivity is imperative to build up and to sustain competitive advantage in today's global service economy. However, service productivity is yet to be thoroughly conceptualized and supported by IT artifacts so as to design, compute, and interpret meaningful productivity models. The purpose of this study is to evaluate the ontological expressiveness of conceptual modeling grammars for service productivity management. Due to a lack of a complete ontology for service productivity management, we compile evaluation criteria by reviewing authoritative theory. Against these criteria, a selection of conceptual modeling grammars is analyzed by reviewing the grammars' meta models for completeness. The analysis contributes

A previous version of this paper is published as: Becker, J.; Beverungen, D.; Knackstedt, R.; Rauer, H.; Sigge, D.: Service Productivity Management—Status Quo and Directions for the Design of Conceptual Modeling Grammars. In: Proceedings of the 45th Hawaii International Conference on System Sciences (HICSS-45). Maui, HI, USA, 2012.

J. Becker · D. Beverungen · H. P. Rauer (✉)
European Research Center for Information Systems (ERCIS), University of Muenster,
Leonardo-Campus 3, 48149 Muenster, Germany
e-mail: hans.peter.rauer@ercis.uni-muenster.de

J. Becker
e-mail: joerg.becker@ercis.uni-muenster.de

D. Beverungen
e-mail: daniel.beverungen@ercis.uni-muenster.de

R. Knackstedt
Institute for Business Economics and Information Systems, University of Hildesheim,
Marienburger Platz 22, 31141 Hildesheim, Germany
e-mail: ralf.knackstedt@uni-hildesheim.de

D. Sigge
Best Practice Consulting AG, Grevener Straße 89, 48159 Muenster, Germany
e-mail: daniel.sigge@bpc.ag

two major insights. First, theory in productivity management appears equivocal and is too unspecific to guide the design of IT artifacts. Second, conceptual modeling grammars are subject to various ontological deficiencies with respect to service productivity management. Two core implications are identified. First, service productivity theories need to be refined as design theories in order to comprehensively inform the design of IT artifacts. Second, conceptual modeling grammars must be extended and aligned with each other.

Keywords Service Science Management and Engineering · Conceptual modeling grammar · Service productivity · Meta modeling · Ontology

1 Introduction

The rise of a world-spanning service economy (OECD 2005) that permeates all industry sectors of modern society creates a strong argument for the design and continuous optimization of service processes. An important metric to reach that end is productivity (Nachum 1999). In goods manufacturing, quantifying productivity traditionally comprises dividing units of output by units of input. However, calculating this measure for services is far more complex due to the distinctive properties of services, such as intangibility, heterogeneity, inseparability, and perishability (Zeithaml et al. 1985). From a different standpoint, Vargo and Lusch (2007) argue that 'service' does not follow the logic of creating units of output at all, but is co-created by service providers and service consumers through an application of knowledge for mutual benefit.

Both strands of research suggest that goods-focused approaches towards productivity management are inappropriate for service productivity management. A manifestation is that many productivity factors are difficult to quantify or are determined by the customer beyond the influence of the service organization. For instance, service quality is an aspect of productivity that is judged subjectively by the beneficiary (Grönroos and Ojasalo 2004; Parasuraman 2002).

As a consequence of the non-transferability of goods-oriented productivity rationales to services, industry struggles with defining a sound service productivity calculus. Most of the approaches suggested in Management Accounting fail to calculate service productivity based on balancing multiple factors of influence, creating one productivity figure. This leaves productivity trade-offs inherent to service systems—such as those between service quantity, service quality, and resource utilization—unresolved. Observing unproductive firms that employ an over- or undersized workforce, Rust and Huang (2012) found empirical evidence that firms have difficulties to balance between using labor or systems to provide service. We, therefore, argue that service productivity management requires IT artifacts (i.e., language constructs, models, methods, and software implementations) that are conceptually different from IT artifacts for managing productivity in a manufacturing setting.

The core of productivity calculations is setting up an appropriate productivity model, including the main factors that influence productivity in a particular context. Popular examples for productivity factors in the service sector are resource utilization, service quality, or service quantity. Setting up the productivity model is a crucial effort that determines all further stages of the calculation, as well as predetermines the results of the calculations themselves. Productivity models can be viewed as a particular manifestation of conceptual models that are frequently used to represent relevant knowledge in a domain. A modeling language is the set of all models that can be built with a conceptual modeling grammar (CMG) (Burton-Jones et al. 2009). A CMG comprises a set of graphical constructs and a set of rules that describe how the constructs can be used in order to create well-formed statements about the world (Wand and Weber 2002). For an easier use by humans, language constructs are often represented by graphical symbols. The graphical symbols that represent the language constructs establish the concrete syntax, i.e., the representational aspect of the language, whereas the rules that govern the use of the constructs constitute the abstract syntax. The semantic meaning of the modeling constructs is only partly defined in CMGs. In most cases, it is established by assigning natural language terms, which are normally not part of the language specification, to the modeling constructs (Juhrisch 2010).

CMGs can inform the design of service productivity models in several ways. First, CMGs can prescribe a language in which productivity models must be expressed in the first place. Second, they can describe the structure of entities and events that influence service productivity, such as the division of work in organizations, the structural properties of physical goods, the properties of activities carried out in service business processes, or customer data inputted into the process. Conceptual models created with the CMG inform service productivity management, too. First, they define the ‘structure’ of a service as a nested hierarchy of service components and attributes. This facilitates the identification of productivity-relevant input and output factors on different levels of abstraction. Second, a conceptual model can serve as a blueprint to transfer productivity metrics between organizations. Third, conceptual models provide means for integrating data from different information systems (Bergamaschi et al. 2011).

Siau and Rossi (2011) suggest that both academic and practical reasons exist for evaluating CMGs. First, an evaluation enables scholars to identify and systematize the most important concepts in a domain, such as service science. Second, practitioners may want to know the particular strengths and weaknesses of CMGs before selecting an appropriate CMG for application in their own firms. Third, CMGs must enable organizations to define complete and consistent productivity models, since productivity calculations must inform organizational decision making. For example, service departments or whole business units might be benchmarked with respect to their productivity as defined in the productivity model. Input factors in the productivity model must cover “the full range of resources”, whereas output factors in the productivity model must “capture all activity levels and performance measures” (Brown 2006, 1103). The grammatical completeness of a CMG can help to comply with these requirements. Fourth, grammatical completeness can also avert that higher benchmarking scores are ascribed to business units operating in a more favorable environment, such as shops being situated in more prosperous neighborhoods than others. This can be achieved by controlling for exogenous variables in the calculus (Emrouznejad and De Witte 2010).

The purpose of this study is to evaluate the ontological expressiveness (Wand and Weber 2002) of selected CMGs in the light of theoretical requirements of service productivity management. Wand and Weber (2002) propose such analyses to be done by comparing the modeling constructs included in a CMG with a set of constructs systematized in an ontology. However, since sufficient ontology support seems to be still unavailable in the area of service productivity management, we compile a set of evaluation criteria by reviewing authoritative theory on service productivity management.

The paper proceeds as follows. In Sect. 2, the approach of utilizing theory for the purpose of evaluating and informing the design of IT artifacts is discussed. A selection of authoritative theory on service productivity management as derived from a literature review is discussed to introduce a set of constructs needed to measure service productivity. In Sect. 3, evaluation criteria for CMGs are derived from these theories. In Sect. 4, a selection of CMGs from service marketing, information systems, and computer science perspectives is evaluated with the proposed criteria in order to assess their ontological expressiveness for service productivity management. In Sect. 5, major insights contributed by the analysis are discussed in order to explore the underlying reasons for the identified ontological deficiencies. Section 6 concludes the paper.

2 Theoretical background

Authoritative literature in the information systems (IS) discipline emphasizes that the design of IT artifacts should be informed by kernel theories (Kuechler and Vaishnavi 2008). A cyclic research process is conducted that comprises of alternating steps of analysis and synthesis. Kernel theories represent validated knowledge that can be used to inform the design of IT artifacts. Consecutively, the design needs to be evaluated in order to assess its applicability, as well as to deduct theoretical knowledge as to why the design works and whether it is superior to rival approaches. Since design is conceptualized as a search process (Hevner et al. 2004), additional cycles of design and evaluation might be conducted until a satisfactory degree of saturation is reached.

2.1 Literature review

In this study, we utilize theory on service productivity management as an analytical lens for assessing the ontological expressiveness of CMGs with respect to service productivity management. To identify a set of seminal theories for service productivity management, a comprehensive, two-phased literature search was conducted from October to December 2010.

In the first phase, we analyzed leading scientific journals (Webster and Watson 2002). A structured literature database search was conducted based on the *VHB-JOURQUAL 2* journal ranking, edited by the *German Academic Association for*

Business Research (VHB) (Schrader and Hennig-Thurau 2009). In particular, the two partial rankings of the fields *Applied Business Administration* and *Service and Retail Management* were selected due to their proximity to service productivity management. Additionally, the journals in the field of *Production* were included, since the traditional understanding of productivity is rooted in this area (Grönroos and Ojasalo 2004; Vuorinen et al. 1998) and we assumed that extensions for measuring the productivity for services might have been published there, as well. From these three partial rankings all 'A+', 'A' and 'B' journals were included in the literature review. Additionally, the journals rated with 'C' in the partial ranking *Service and Retail Management* were included as well, due to their particular relevance for the service sector. As a result of this selection process, 40 journals were identified and subsequently analyzed in-depth. Since distinguishing *productivity* from related concepts such as *efficiency* and *performance* is somewhat equivocal in the literature (Emrouznejad and De Witte 2010; Käpylä et al. 2010; Linna e al. 2010), 17 combinations of search terms were used in order to identify the seminal theories in this area (cf. Table 1). From this process, 215 journal papers were identified from which three papers comprehensively elaborate on the conceptual underpinnings of service productivity (Corsten 1994; Grönroos and Ojasalo 2004; Parasuraman 2002; Vuorinen et al. 1998).

The structured literature search was complemented by a second phase that employed catalogs and online search engines in order to include other scientific

Table 1 Keywords employed in the database search

Category "Productivity"	Category "Efficiency"	Category "Performance"
Title: productivity *AND* service	**Title:** efficiency *AND* service	**Title *OR* Abstract:** "service performance" *OR* "performance of service" *OR* "performance in service"
Title *OR* Abstract: "productivity model" *OR* "model of productivity"	**Title *OR* Abstract:** "efficiency model" *OR* "model of efficiency"	
Title *OR* Abstract: "productivity concept" *OR* "concept of productivity"	**Title *OR* Abstract:** "efficiency concept" *OR* "concept of efficiency"	**Title *OR* Abstract:** ("performance model" *OR* "model of performance") *AND* "service"
Title *OR* Abstract: "theory of productivity" *OR* "theory on productivity" *OR* "productivity theory"	**Title *OR* Abstract:** "theory of efficiency" *OR* "theory on efficiency" *OR* "efficiency theory"	**Title *OR* Abstract:** ("performance concept" *OR* "concept of performance") *AND* "service"
Title *OR* Abstract: "productivity framework" *OR* "framework of productivity" *OR* "framework for productivity"	**Title *OR* Abstract:** "efficiency framework" *OR* "framework of efficiency" *OR* "framework for efficiency"	**Title *OR* Abstract:** ("theory of performance" *OR* "theory on performance" *OR* "performance theory") *AND* service
Title *OR* Abstract: "service productivity" *OR* "productivity of service" *OR* "productivity in service"	**Title *OR* Abstract:** "service efficiency" *OR* "efficiency of service" *OR* "efficiency in service"	**Title *OR* Abstract:** ("performance framework" *OR* "framework of performance" *OR* "framework for performance") *AND* service

work, such as dissertations, in the review. As a result of this less structured phase, two service productivity theories were identified in addition.

In Fig. 1, the results of the literature search process are summarized. The four theories that are selected as theoretical fundament for service productivity in this article are visualized as white boxes. The gray-shaded boxes represent approaches that do not constitute fully-fledged productivity conceptualizations, even if they do provide important theoretical foundations for the remainder of this work. Some of these approaches inspired the development of other service productivity theories, as indicated by the arrows contained in the figure. The numbers indicate whether a theory was identified in the first or second round of the search process.

2.2 Seminal theories for service productivity management

Corsten (1994) claims that a service provider needs to establish the capabilities to provide a service, before the service is created in a subsequent step of value co-creation with the customer. Accordingly, the productivity of the pre-combination phase is distinguished from the productivity of the end-combination phase (cf. Fig. 2). The pre-combination phase is created autonomously by the service provider. Input resources are consumed in order to prepare for service provision. This co-called *achievement potential* is stored until the service is requested by the customer at a 'moment of truth'. The productivity of the pre-combination phase is calculated by dividing the achievement potential by the input factors consumed.

The achievement potential itself serves as an input factor for the end-combination phase, but is at the same time the output of the pre-combination phase. In case a customer requests a service, a fraction of the achievement potential is channeled into the service delivery process. In addition, the service provider usually has to provide other inputs not contained in the achievement potential. Since services by definition require a degree of customer involvement, external input factors have to be taken into account during the end-combination phase, too. For example, objects, people, or information inputted by the customer must be considered. The ratio of the

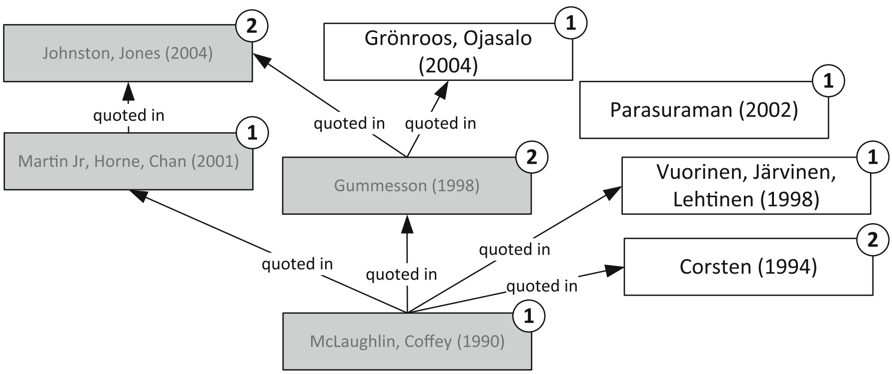

Fig. 1 Identified service productivity theories

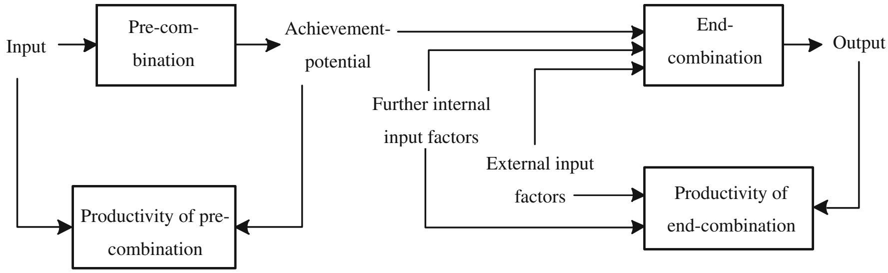

Fig. 2 Service productivity as conceptualized by Corsten (1994)

service output factors and the input factors consumed in the service process constitutes the productivity of the end-combination phase.

The achievement potential is further detailed. First, it can be represented by quantitative and qualitative indicators, all of which can be weighted according to customer or expert surveys and then be combined into an overall quality index. Second, a distinction is made between the offered achievement potential and the utilized achievement potential. This takes into account that a customer's demand can be lower than the capacity offered by the service provider. Therefore, the portion of utilized achievement-potential as opposed to the offered achievement-potential is incorporated into the productivity ratio of the pre-combination phase.

Vuorinen et al. (1998) view service productivity as focused at a certain point in time, i.e., from a static perspective. They state that service productivity constitutes conventional productivity metrics and service quality considerations. Consequently, service productivity is conceptualized "as the ability of a service organization to use its inputs for providing services with quality matching the expectations of customers" (Vuorinen et al. 1998, 380). The view on quantity and quality as inseparable dimensions of productivity that cannot be examined in isolation is expressed in the following general formula:

$$\text{Service productivity} = \frac{\text{Quantity of output and quality of output}}{\text{Quantity of input and quality of input}}$$

Quantitative aspects represent the traditional output-divided-by-input conceptualization of productivity. Input factors can be further subdivided into raw materials, capital, and labor. Output quantity refers to the service volume provided, such as the "number of transactions or actual service hours" (Vuorinen et al. 1998, 384). The "output may consist of highly customized services (…), and the definition of the service output becomes a more laborious task. This task is often complicated by the intangible nature of services." (Vuorinen et al. 1998, 381). *Qualitative aspects* are examined for both input factors and output factors. Output quality is not assessed from an internal, technical, or functional viewpoint but rather from the customer's perspective. On the input side, tangible quality elements are distinguished from intangible quality elements. The layout of a store, for instance, constitutes a tangible element of input quality that influences customer's expectations of the service. Major concepts of this service productivity concept are depicted in Fig. 3.

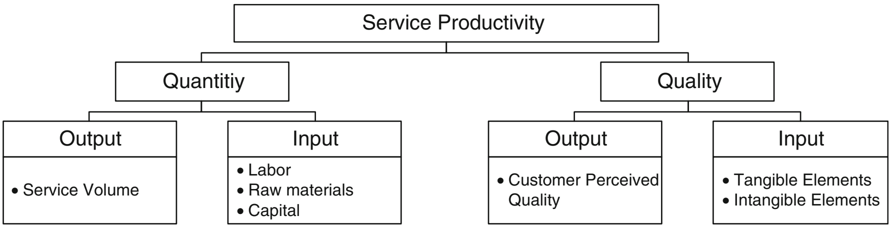

Fig. 3 Service productivity as conceptualized by Vuorinen et al. (1998)

Parasuraman (2002) argues against including service quality into the productivity calculus as a concept in its own right, but suggests including service quality as a mediating concept between the provider and the customer (cf. Fig. 4). From a service provider's perspective, input factors such as labor, equipment or technology are transformed into outputs such as sales, profits, or market share. Output refers to the incentives and goals of the service provider, but also highlights value co-creation, since customers "often play a co-production role, providing some amount of direct or indirect input" (Parasuraman 2002, 7).

The dashed arrows in Fig. 4 indicate relationships between both perspectives and service quality. Higher levels of inputs provided by a service company will likely increase service quality, while higher levels of customer inputs may have the inverse effect. Higher service quality, in turn, has a positive effect on the outputs perceived by service provider and service customer. Moreover, there are three direct effects between the two perspectives, visualized as solid arrows: (1) substitution effects between the input factors of service providers and customers may be present, depending on the division of labor between both actors. The intensity of this effect depends on the allocation of resources (2), since increasing the service company's inputs in the wrong place might have no or only little impact on the amount of customer input required. On the output side, an increase of output from the customer's perspective is claimed to have a positive effect on the output as perceived from the service company's perspective (3), such as an increased willingness to pay for superior service.

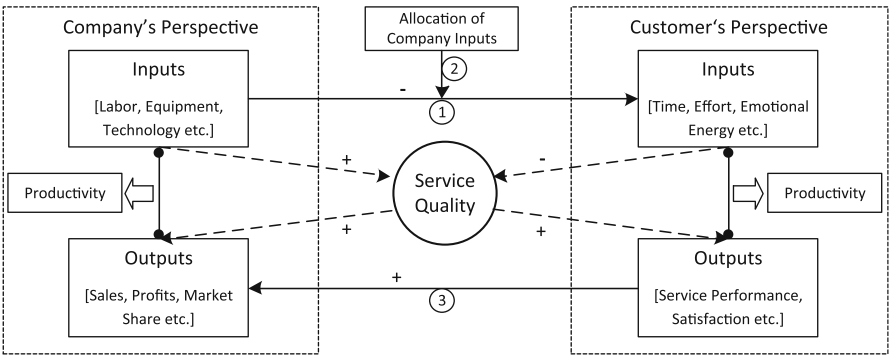

Fig. 4 Service productivity as conceptualized by Parasuraman (2002)

Grönroos and Ojasalo (2004) perceive service processes as open systems in which customers are directly and often simultaneously involved. Standardization in such systems is only partially possible, leading to varying service quality and precluding quantitative output metrics. In addition, activities contained in a service process are identified as three sub-processes according to the level of customer involvement. Accordingly, activities can either be conducted by the service provider in isolation, cooperatively by the provider and the customer, or by the customer only. These sub-processes are directly (solid arrows in Fig. 5) or indirectly (dashed arrows in Fig. 5) influenced by different input factors and can affect different aspects of the service output. On the input side, the contribution of the service provider is distinguished from the contribution of the customer. Customer input is further subdivided into inputs provided by the actual customer and inputs provided by other customers. Such inputs are important with regard to services provided on web-based service marketplaces. On the output side, quantitative aspects are distinguished from qualitative aspects. Quality partly manifests in the production and delivery process (*interaction-induced quality*), as well as in the outcome generated in this process (*outcome-induced quality*). Both quality dimensions are filtered by the company's image, leading to the *customer perceived quality*.

Thus, three types of efficiency are suggested. Internal efficiency refers to how efficient a company transforms resources into internal outputs. External efficiency refers to the ability of a company to provide a high amount of perceived quality, i.e., "how effectively it creates external interest in the output" (Grönroos and Ojasalo 2004, 416). Capacity efficiency is about superior resource utilization, which is challenged by the fact that services cannot be stored or produced in advance of customer demand.

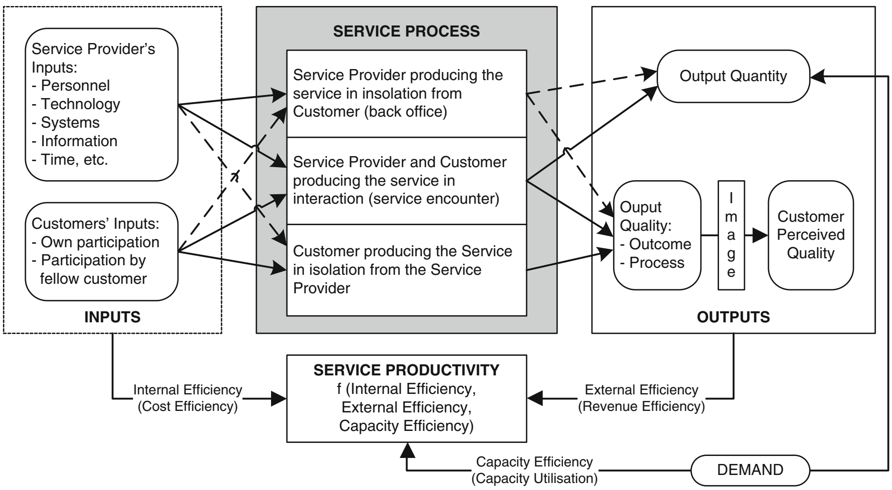

Fig. 5 Service productivity as conceptualized by Grönroos and Ojasalo (2004)

3 Evaluation criteria

From the presented theories, a set of criteria for evaluating the ontological expressiveness of CMGs in the area of service productivity management is derived. Notably, other factors, such as compliance with the information systems in service companies or the abilities of service professionals to correctly apply CMGs in modeling projects, have been excluded to keep the analysis focused on how well existing CMGs can represent the domain requirements of service productivity management. Furthermore, we consolidated aspects proposed by more than one theory in order to keep the set of criteria balanced. For example, both Grönroos and Ojasalo (2004) and Vuorinen et al. (1998) highlight the importance of quantitative measurements for service output. Since Grönroos and Ojasalo address this concept in more detail, we excluded the same concept in Vuorinen et al. For a full list of the concepts, see (Becker et al. 2012).

In line with Corsten (1994), a CMG has to provide constructs to separately depict the pre- and the end-combination phase of service provision ([1.1]). A sophisticated way to do this is to provide different modeling contexts for both phases and for the association of multiple end-combinations to the same pre-combination. In addition, CMGs need to contain constructs for depicting inputs and outputs of both phases ([1.2], [1.3]). Whereas the inputs for the pre-combination phase do not need to be further specified, the inputs of the end-combination phase need to be distinguished with respect to their origin. A CMG should be able to distinguish internal from external input factors to enable productivity analyses from both perspectives as well as the impact of shifting service activities between the involved actors ([1.4]). The achievement potential deserves special attention due to its mediating role between the two phases ([1.1.1]). First, a CMG should support quantitative ([1.1.1.1]) and qualitative ([1.1.1.2]) aspects. Different quality indicators should be supported and weighted to display the overall quality needs in the models. Second, a differentiation between the offered and the utilized achievement potential is important to analyze the degree of resource utilization. Other concepts regarding outputs were omitted since other theories draw a clearer picture of service outputs (cf. Table 2).

In line with Vuorinen et al. (1998), CMGs need to provide constructs for the inputs channeled into the production process and for outputs that are created by a service. Both quantitative and qualitative characteristics need to be identified ([2.1]–

Table 2 Requirements towards CMGs for productivity modeling, based on Corsten (1994)

1	Corsten (1994)
[1.1]	Individual modeling of pre- and end-combination
[1.1.1]	Depiction of the achievement potential, especially its intermediate role
[1.1.1.1]	Depiction of quantitative aspects of the achievement potential
[1.1.1.2]	Depiction of qualitative aspects of the achievement potential
[1.2]	Depiction of input factors for the pre-combination
[1.3]	Depiction of input factors for the end-combination
[1.4]	Demarcation of internal and external input factors

[2.4]). As inputs, language constructs for labor, raw material, and capital must be considered ([2.1.1]–[2.1.3]). Providing individual language constructs for the three types of inputs is advisable to allow for a differentiated modeling of all quantitative service inputs. Labor, for example, may be described by information like hourly wages, qualification profiles, and overtime fees. This information is clearly not of interest for specifying costs for raw materials and capital. Second, CMGs need to account for tangible and intangible elements of input quality ([2.2.1], [2.2.2]), since both quality aspects require different parameterizations and measurement approaches. Modeling the service quality perceived by a customer are excluded, since Grönroos and Ojasalo (2004) depict these in far greater detail ([4.6]–[4.8]). The discussed requirements of CMLs are summarized in Table 3.

The framework of Parasuraman (2002) describes the productivity of services from a retrospect point of view. Therefore, a CMG needs to support the modeling of input factors, distinguished by their origin, as suggested by Corsten (1994). Parasuraman (2002) names some examples for internal and external input factors, in order to convey a general idea about how input factors from both perspectives could look like. We exclude these factors in favor of the more detailed requirements on inputs suggested by Grönroos and Ojasalo (2004).

On the output side, the derivation of requirements on CMGs is not equally evident. This is due to the fact that especially the outputs from the service company's perspective, exemplified by the metrics 'sales', 'profits' and 'market share', are not defined in a product-related way. In combination with the transactional data of past service provisions, this information is essential for calculating, for example, the 'profit' generated within a certain period of time. Thus, economic indicators of service provision (especially costs and prices) are considered the best approximation ([3.2]). Furthermore, a separate depiction of outputs from the customer's perspective needs to be made ([3.3]). It is important to clearly differentiate between the internal and external view on the service output to be able to assess a customer's productivity in the service process. Thus, an emphasis is put on differentiating the output perspectives. Outputs from the customer's perspective, such as "service performance" or "satisfaction", seem quite ambiguous. However, they are considered as requirements in order to make sure that the strong focus on such "soft" output factors is properly reflected ([3.3.1 e], [3.3.2 e]). Quality plays an important mediating role between both productivity perspectives. However, this

Table 3 Requirements towards CMGs for productivity modeling, based on Vuorinen et al. (1998)

2	Vuorinen et al. (1998)
[2.1]	General depiction of quantitative input factors
[2.1.1]	Depiction of labor input
[2.1.2]	Depiction of raw material input
[2.1.3]	Depiction of capital input
[2.2]	General depiction of qualitative input factors
[2.2.1]	Depiction of intangible quality elements
[2.2.2]	Depiction of tangible quality elements

concept is going to be depicted more accurate in requirements ([4.2]–[4.2.2]). The requirements that can be inferred from the service productivity theory are summarized in Table 4.

From the theory contributed by Grönroos and Ojasalo (2004), several criteria can be derived. First, the resources channeled into the production process need to be addressed. In order to analyze the contribution of customers and service providers separately, a further distinction between these two input types is necessary. However, these requirements are already covered by the concept [1.4] and are therefore excluded. However, a differentiation between direct customer inputs and indirect customer inputs (i.e., provided by fellow customers) should be offered by the CMG ([4.1]). Besides, the requirements on input factors ([2.1.1]–[2.1.3]) suggested by Vuorinen et al. (1998), Grönroos and Ojasalo (2004) identify some more categories of inputs from the provider such as the information [4.2 e], systems [4.3 e], the technology [4.4 e] and time [4.5 e].

The output of the service process needs to be educible by modeling both quantitative and qualitative aspects. The quantitative aspect, transformed to the level of single products (i.e., on the type level of product models), is interpreted as quantitative service characteristics, as presented in requirement [2.3]. In addition, customer perceived quality is included ([4.2]). It is disputable, whether a further specification of outcome and process quality aspects is necessary or even a meaningful concept in product models. However, a distinct treatment of both aspects can be formulated that builds upon the general requirement of depicting customer perceived quality ([4.2.1]). In addition, capacity efficiency is included as forecasted figures or planning data [4.4], since such information—in combination with capacity information—is necessary to compute the expected capacity utilization. A summary of the requirements is presented in Table 5.

4 Evaluation

To evaluate the ontological expressiveness of CMGs for service productivity management, we focus on identifying what Burton-Jones et al. (2009) as well as Recker et al. (2011) describe as construct deficits. These deficiencies are identified if constructs that exist in the ontological model—which was compiled based on service productivity theories—are missing in the set of modeling constructs comprised in a CMG. On the other hand, a CMG is considered complete if a

Table 4 Requirements towards CMGs for productivity modeling, based on Parasuraman (2002)

3	Parasuraman (2002)
[3.1]	Depiction of economic indicators (esp. prices and costs)
[3.2]	Separate depiction of output factors from the customer's perspective
[3.2.1 e]	Depiction of customer satisfaction
[3.2.2 e]	Depiction of service performance

Table 5 Requirements towards CMGs for productivity modeling, based on Grönroos and Ojasalo (2004)

4	Grönroos and Ojasalo (2004)
[4.1]	Demarcation of direct and indirect external input
[4.2 e]	Depiction of information input (internal)
[4.3 e]	Depiction of systems input (internal)
[4.4 e]	Depiction of technology input (internal)
[4.5 e]	Depiction of time input (internal)
[4.6]	General depiction of customer perceived quality
[4.6.1]	Depiction of outcome (technical) quality
[4.6.2]	Depiction of process (functional) quality
[4.7]	Depiction of the quantitative service output
[4.8]	Depiction of demand (and capacity utilization) aspects

bijective mapping between a CMG's representations and real-world phenomena exists.

An abundance of CMGs has been proposed for modeling phenomena related to services. A general overview is offered by Oberle (2012), as well as by Barros and Oberle (2012, 18) in their *Handbook of Service Description*. An analysis on business-oriented approaches for modeling product-service systems from various perspectives is provided in (Becker et al. 2009a, b) and (Becker et al. 2012). Razo-Zapata et al. (2012) discuss technical and business-related aspects of approaches to compose value propositions (called 'service networks' there). Ferrario et al. (2012) take the perspective of modeling service systems and service ecosystems against the backdrop of the emerging discipline of Service Science. Regarding technical (i.e., software-based) services as IT artifacts, Kohlborn and la Rosa (2012) discuss approaches related to describe, retrieve, and compose technical (i.e., electronic) services in service-oriented architectures (SOA). From a semantic and artificial intelligence point of view, Heymans et al. (2012) present approaches for automating web service discovery and composition, whereas Pedrinaci et al. (2012) focus on comparing semantic web services approaches.

The purpose of this article is to explore the support of current approaches for service productivity modeling, focusing on how to model, measure, and interpret the efficiency of *business service* portfolios. Therefore, from the rich array of methods discussed above, our analysis focuses on comparing seven CMGs for modeling business services with each other, while excluding modeling approaches that focus on software-based services, for the time being. An overview on each CMG's authors, domain and original purpose is reported in Table 6. Since service science is a multi-disciplinary research field (Bardhan et al. 2010), this selection was made to include a variety of perspectives from different domains. The selected approaches comprise H2-ServPay, the e^3family of ontologies, and the Service Network Notation as approaches to model, configure, and offer service bundles, the recently proposed Unified Service Description Language (USDL) as standard for service description, the Molecular Model as a Service Marketing approach to offer services, and the

Table 6 Overview of the examined CMGs

CMG	Current developers	Purpose	Domain
H2-ServPay (Becker et al. 2009a)	European Research Center in Information Systems (ERCIS)	To jointly model, configure, and price bundles of physical goods and services (i.e., Product-Service-Systems)	Service Science Management and Engineering, Information Systems
e^{3}Family (Razo-Zapata et al. 2011) (Gordijn and Akkermans 2001) (De Kinderen 2010)	Free University Amsterdam	To build and analyze offerings at design time and to foster the configuration of offerings for a customer at run time	Service Science Management and Engineering, Information Systems
SNN (Danylevych et al. 2010)	University of Stuttgart	To model interconnections of services offered and required by actors that shape complex webs	Service Science Management and Engineering
USDL (SAP Research 2011)	SAP research and the THESEUS/ TEXO research projects	To model service networks in a general and generic form, from a technical and business perspective; to allow services to become tradable and consumable	Computer Science, Semantic Web, Ontology
Molecular model (Shostack 1977)	Discontinued	To depict intangible aspects of products	Service Marketing/ Product Marketing
eEPC (Scheer 1998, 2000)	IDS Scheer AG nowadays owned by Software AG	To provide specify business processes in a graphical notation	Information Systems
BPMN 2.0	Object Modeling Group (OMG)	To provide a graphical notation for specifying business processes	Computer Science, Workflow Management

eEPC and BPMN as standard languages for modeling business processes and workflows.

Throughout the following sections we apply the catalog of service phenomena, developed in Sect. 3, to each of the CMGs. Based on this analysis, the ontological expressiveness of CMGs—with respect to covering the theoretical constructs required in service productivity management—are documented, whereas any existing construct deficits are identified.

For each criterion, four rating levels are defined. The fundamental criterion for assigning a rating level is whether each of the requirements is explicitly supported by a construct in the CMG or not. The rating level '++' indicates, that a requirement is explicitly covered by the CMG with a construct. If the constructs provided in the CMG address the requirement to some extent, the rating level '+' is assigned. In case a requirement is not explicitly supported, it might be possible to use other constructs such as text to compensate for the missing construct (rating level '−'). In case a requirement is not supported at all, the level '−−' is assigned.

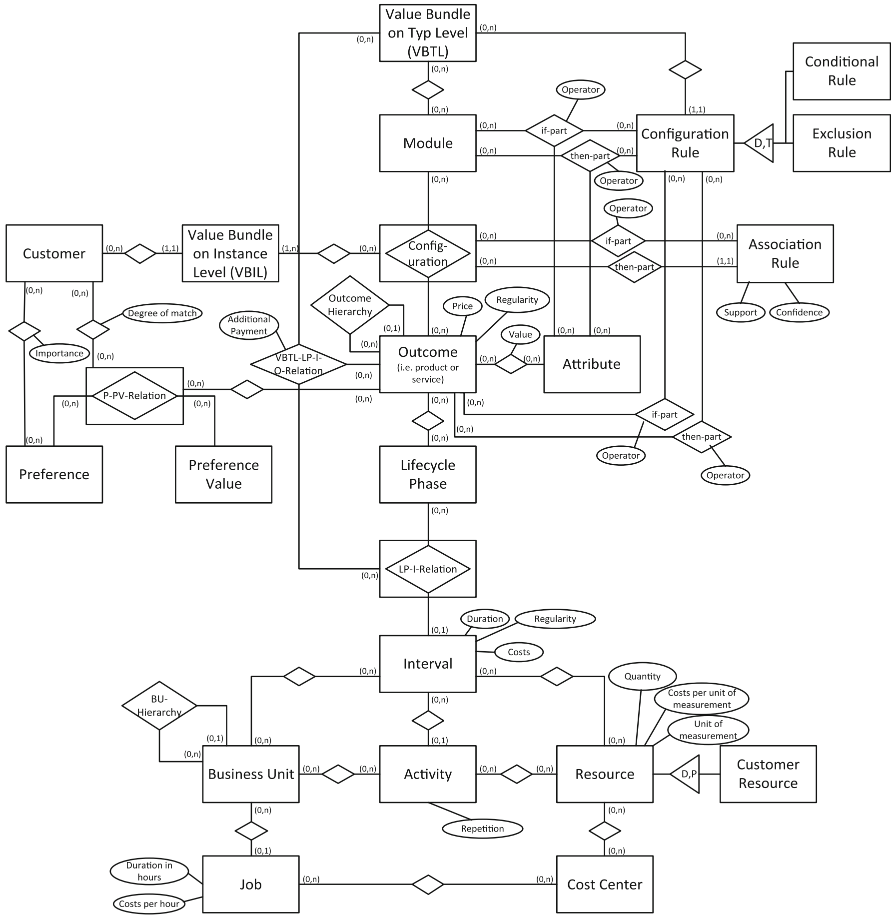

Fig. 6 Meta model of H2 ServPay (Becker et al. 2009a)

Just like in Becker et al. (2009a, b), the rating was performed based on reviewing the meta models of the CMGs. Meta models are frequently analyzed for assessing and comparing modeling languages (Siau and Rossi 2011). Since some of the analyzed CMGs did not come with a meta model, some meta models needed to be reconstructed in the *extended Entity-Relationship Model* (eERM) notation (Chen 1976; Scheer 1998). The rating procedure itself was conducted by three researchers independently from each other. In a follow-up discussion, any inconsistent ratings were resolved. This mainly focused on the compensation of ontological deficiencies with general modeling constructs, such as plain text.

4.1 H2-ServPay

The *H2-ServPay* modeling grammar (Becker et al. 2009a) was developed for jointly modeling, configuring, and pricing bundles of physical goods and services. The calculation of cost data and the estimation of the customers' willingness to pay for a service were central design objectives. These calculations require language constructs for resources, prices, outcomes and lifecycle data, which are relevant in service productivity management, too. The meta model is depicted in Fig. 6.

On the input side, *Resource* is the most important construct. It can be used to model arbitrary input factors. Although a comprehensive resource concept is not provided, human resources (i.e., the input factor labor) have a special status. They can be specified and clustered in *Business Units* that in turn can be embedded in nested hierarchies. Qualitative aspects cannot be modeled in a meaningful way. *H2-ServPay* offers the construct *Customer Resource* in order to model customer's input into the service process, even if it ignores any idiosyncrasies of internal and external inputs.

The value proposition of a single service or a bundle can be thoroughly depicted by using the construct *Outcome* and its self-referential relationship (*Outcome Hierarchy*). It allows creating a detailed model of the different components of the service offering, although a further differentiation of output types is not provided. Quantitative and qualitative outputs can be modeled with the generic construct *Attribute*. This allows modeling essentially any output-related information that is deemed relevant by the modeler. However, H2-ServPay fails to separate the customer's and the service provider's perspective consistently. More differentiated modeling constructs would be required for this purpose. Detailed constructs are provided for modeling the economic results of a service offering for service providers and service customers. The costs of value bundles can be comprehensively depicted throughout their whole lifecycle and can be set into relation with market prices. Thus, H2-ServPay allows for modeling the "company's output in broad terms".

4.2 e^{3}family

The e^{3}family is a comprehensive set of ontologies that can be used for modeling offerings comprising goods and services, referred to as *service value networks* (Razo-Zapata et al. 2012). One descendant of the e^{3}family is a combined approach that has been designed by combining the original ontologies of e^{3}value (Gordijn and Akkermans 2001) as a CMG to build and analyze offerings at design time, with e^{3}service (De Kinderen 2010) as a CMG to foster the configuration of offerings for a customer at run time, by Razo-Zapata et al. (2011). The meta models of this approach are depicted in Fig. 7.

The e^{3}family contains modeling constructs for depicting a provider's as well as a customer's point of view on value creation. From the provider's point of view, *Actors* are independent economic entities. On an operational level, they perform *Value Activities* in order to create *Service Bundles*, comprised of *Service Elements*. *Value Offerings* denote what actors provide to or request from their environment. They are created via *Value Interfaces* in a reciprocal fashion of value co-creation, and are offered via *Value Ports* to external *Actors*. *Value Objects* are things that are valuable for more than one *Actor*, and are exchanged by them in acts of cooperative value creation. *Value Objects* have *Consequences* that can be *Quality Consequences*

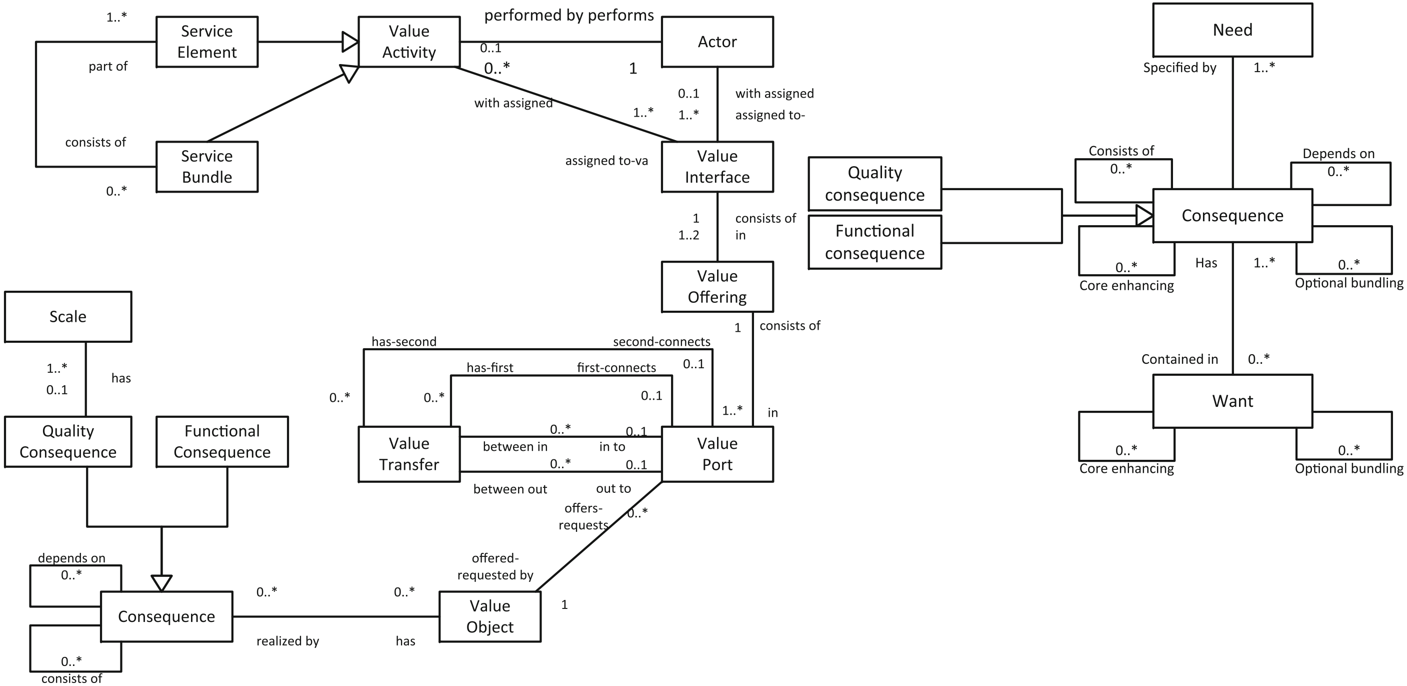

Fig. 7 Meta models contained in the e^3-family (Razo-Zapata et al. 2011): Supplier perspective based on aligning the e^3-value (Gordijn and Akkermans 2001) and e^3service ontologies (De Kinderen 2010) (*left*); customer perspective of the e^3-service ontology (*right*)

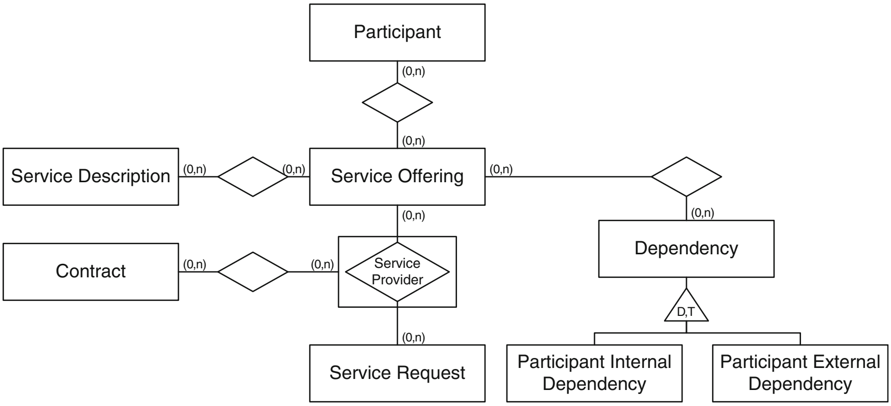

Fig. 8 Re-engineered meta model of the Service Network Notation

and *Functional Consequences*. *Quality Consequences* of the same type are grouped together as *Scales*. From a customer's point of view, *Needs* denote a problem statement or goal. *Consequences*, that can be either *Quality Consequences* or *Functional Consequences*, result from consuming valuable service properties. A *Want* is a solution offered on the market that conveys a set of *Consequences* (Gordijn and Akkermans 2001; De Kinderen 2010; Razo-Zapata et al. 2011).

The assessment of the ontological expressiveness of the e^{3}family in terms of service productivity management suggests that sufficient constructs are provided for modeling qualitative outputs of services such as customer satisfaction or perceived quality, while quantitative outputs can be modeled with the construct *Value Transfer*. On the other hand, inputs—other than activities in a service process—are not covered at all, which renders the approach inapplicable for productivity calculation. The modeler can distinguish value bundles as a pre-combination

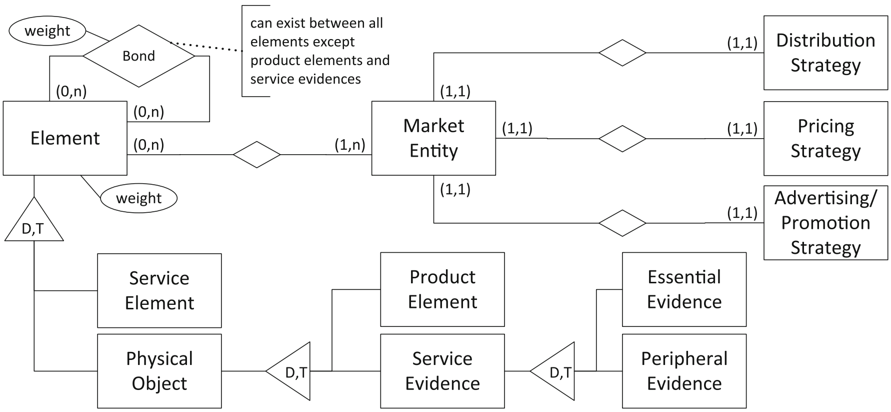

Fig. 9 Re-engineered meta model of the molecular model (Becker et al. 2009a, b)

(i.e., *Value Offering*) from value bundles as an end-combination (i.e., *Value Object*). However, the achievement potential cannot be described by any qualitative or quantitative metrics, due to a lack of modeling constructs.

4.3 Service Network Notation (SNN)

The Service Network Notation (SNN) was designed to model interconnections of services offered and services required by actors that shape complex webs (referred to as service networks) (Danylevych et al. 2010). SNN suggests that *Participants*—individuals or business entities—can issue *Service Requests* and *Service Offerings*. The relationships amongst participants are modeled as *Business Relationships* (e.g., strategic alliances), *Structural Relationships* (e.g., super- and sub-ordinate organizational units), or as *Service Providings* (i.e., the actual delivery of a service). *Service Offerings* are further described with functional and non-functional properties. The idea of SNN is to match *Service Offerings* in a network with fitting *Service Requests*, and allows for modeling multiplicity and timing between those entities, as well. In order to facilitate an alignment of value propositions and business processes in a service network, the authors suggest a method for transforming SNM models into BPMN models. Since Danylevych et al. (2010) do not offer a meta model for their approach, we present a re-engineered meta model in Fig. 8.

An evaluation with the proposed criteria suggests that SNN can distinguish a pre-combination of services (i.e., *Service Offering*) from an end-combination (i.e., *Service Request)*. In addition, dependencies between services can be modeled, such that a hierarchy of components can be modeled. However, the approach is very limited in terms of modeling any input factors or output factors, since this information can only be modeled with the generic constructs *Service Description* or *Contract*. This suggests that SNN has been designed for matchmaking service offers with service requests, but not for computing service productivity based on a productivity model comprising inputs and outputs.

4.4 Molecular model

The *Molecular Model* postulates the concept of market entities. Atomic (inseparable) services and products can act simultaneously to form a larger, connected and unique 'molecular' configuration (Shostack 1982). It provides means to make such market entities explicit in models. Since no meta model has been supplied, we reconstructed it from a selection of models that were instantiated with the grammar (cf. Fig. 9).

A *Market Entity* (e.g., 'automobile' or 'maintenance service') consists of several (or at least one) *Elements*. This element is either a *Service Element* or a *Physical Object*, further subdivided into *Product Element* and *Service Evidence*. The *Product Element* (e.g., 'vehicle') is the tangible complement of the *Service Element* (e.g., 'transportation'). The construct *Service Evidence* represents "physical objects which cannot be categorized as true product elements." (Shostack 1982) It is again subdivided into the constructs *Peripheral Evidence* and *Essential Evidence*.

Peripheral Evidence is a physical representation of a service (e.g., a flight ticket representing a transportation service). An *Essential Evidence* is an object that is related to a service (e.g., a new aircraft, suggesting that a transportation service will be of high quality) that cannot be possessed by the customer but may nonetheless profoundly impact on the service purchase.

Since the *Molecular Model* originated from Service Marketing, it incorporates all four elements of the classical marketing mix: product, price, placement and promotion (Wierenga 2012). The product is modeled with the construct *Market Entity*, as discussed before. The other three aspects seem to be only superficially supported by the constructs *Distribution Strategy*, *Pricing Strategy* (i.e., costs and prices) and *Advertising/Promotion Strategy*. In an instantiated model, they are more or less described in natural language (Shostack 1982).

Relationships between the aforementioned types of *Elements* are modeled by using the construct *Bond*. They generally depict decisions, affiliations, mutual influences, correlations etc. To these *Bonds*, and also to the *Elements* themselves, an attribute *weight* can be attached. This construct reflects the possibility of emphasizing certain aspects, for example according to customer preferences, or to exhibit clusters of components having a high correlation (Shostack 1982).

An evaluation of the *Molecular Model* reveals that it is not quite suitable for modeling productivity-related information, since virtually none of the items listed in the catalog of requirements are covered by language constructs designed for this purpose. Moreover, the *Molecular Model* does not provide any generic constructs that could be used to depict provisional information like resource origin or quality indicators. The only exception is modeling the service outcome. Due to its focus on marketing, the *Molecular Model* can model the components that make up a *Market Entity*. The constructs *Peripheral* and *Essential Evidence* can be used to model components that have an impact on service perception. The *Pricing Strategy* can be used to depict some basic economic indicators of a service.

4.5 Unified service description language (USDL)

USDL was designed for describing business and software services with all aspects relevant to support their discovery and combination in the envisioned ecosystem “Internet of Services” (Barros and Oberle 2012). It can describe services from a business and an operational point of view and aligns this information with a technical perspective to allow digital services to become tradable and consumable. Services that can be modeled with USDL, can be executed by humans (e.g., project management), transactional (e.g., purchase order requisition), informational (e.g., demographic queries), software component (e.g., software widgets for download), digital media (e.g., video and audio clips), platform (e.g., middleware services such as message store-forward) and infrastructure (e.g., CPU and storage services) services (SAP Research 2011). This generic applicability is enabled by a considerable amount of modeling constructs covered by USDL that can be tailored to specific domains. Nine different modules (Fig. 10) enable modeling legal aspects, pricing, service levels or different roles of the participants in a service process. A detailed overview is available in (SAP Research 2011).

An overview of USDL from the perspective of software services has been performed by Birkmeier et al. (2012). Since we abstracted from technical services (such as web services) in this paper, we focus on the ability of USDL to model business services, instead.

Although USDL seems to lack sufficient constructs for modeling the pre-combination of services in sufficient detail for productivity calculation, many constructs are provided that are needed for service productivity management. *ExposedResources* can be used to model inputs in a service process. With *ResourceType*, another construct is provided to depict general resources, e.g., *SoftwareResource*, *InformationResource*, *HumanResource* or *PhysicalResource*. There is a detailed differentiation between the involved actors in the service process in the *Participants* module, distinguishing *providers*, *businessOwners*,

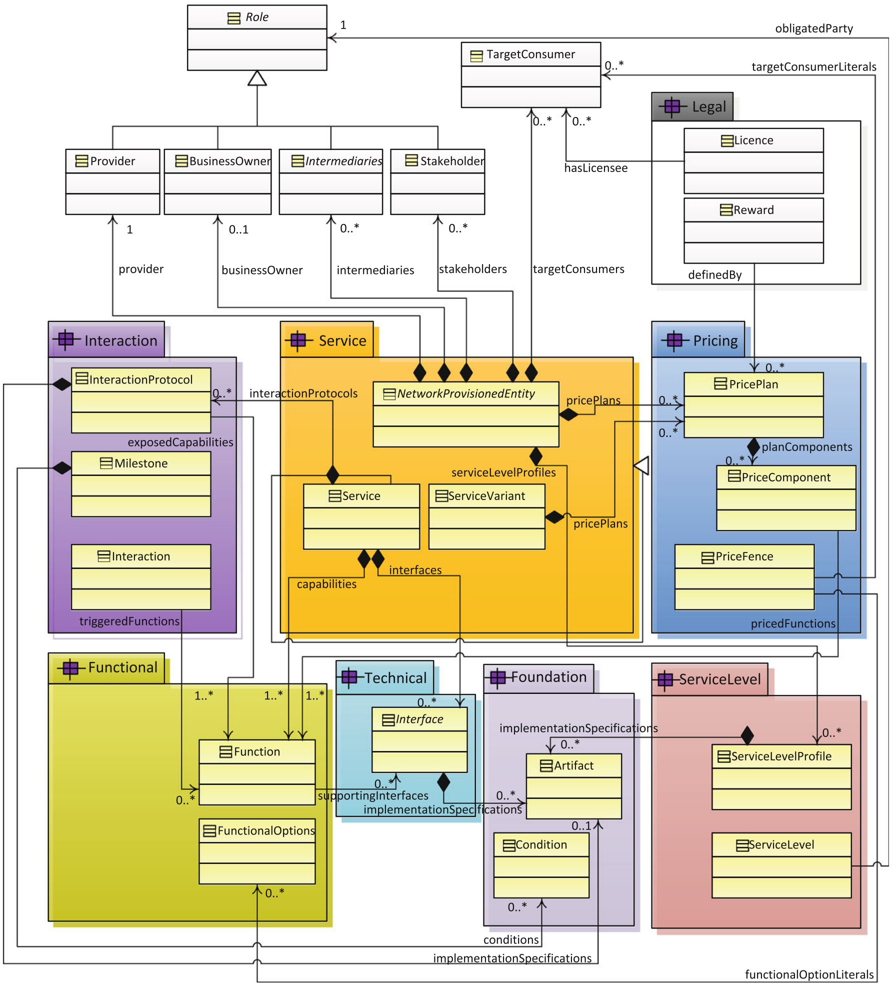

Fig. 10 Interconnected elements of the USDL modules (SAP Research 2009)

Table 7 Ontological expressiveness of selected CMGs for service productivity management

Analysis of the CMGs meta models with respect to the proposed evaluation criteria		H2-ServPay	e^3family	SNN	Mol. model	eEPC	BPMN	USDL
Corsten (1994)								
[1.1]	Individual modeling of pre- and end-combination	+	++	++	−−	−	+	−−
[1.1.1]	Achievement potential, especially its intermediate role	−	−	−	−−	−	+	−−
[1.1.1.1]	Quantitative aspects of the achievement potential	+	−−	−	−−	+	−−	−−
[1.1.1.2]	Qualitative aspects of the achievement potential	−	−−	−	−−	−	−−	−−
[1.2]	Input factors for the pre-combination	−	−	−−	−−	+	−	−−
[1.3]	Input factors for the end-combination	+	−−	−−	−	+	−	++
[1.4]	Demarcation of internal and external input factors	−	−	−−	−−	+	+	+
Vuorinen et al. (1998)								
[2.1]	General depiction of quantitative input factors	+	−	−	−	+	−−	+
[2.1.1]	Labor input	+	++	−−	−	++	−−	++
[2.1.2]	Raw material input	+	−−	−−	−−	−	−−	++
[2.1.3]	Capital input	+	−−	−−	−	++	−−	−
[2.2]	General depiction of qualitative input factors	++	−	−−	−−	−	−	+
[2.2.1]	Intangible quality elements	−	−	−−	−−	−−	−−	−−
[2.2.2]	Tangible quality elements	++	−−	−−	−−	−−	−−	++
[2.3]	Quantitative service output	−	++	−−	−−	+	−	+
[2.4]	Customer perceived quality	−−	++	−−	−−	−	−−	−
Parasuraman (2002)								
[3.1]	Economic indicators	−−	−−	−−	−	++	−−	++

Table 7 continued

Analysis of the CMGs meta models with respect to the proposed evaluation criteria		H2-ServPay	e³family	SNN	Mol. model	eEPC	BPMN	USDL
[3.2]	Separate depiction of outputs from customer's perspective	+	++	+	−−	−	−	−
[3.2.1 e]	Customer satisfaction	−	++	−−	−−	−	−−	−−
[3.2.2 e]	Service performance	++	++	−	−−	−	−−	++
Grönroos and Ojasalo (2004)								
[4.1]	Demarcation of direct and indirect external input	−	−	−−	−−	−−	−−	+
[4.2 e]	Information (internal)	−	−	−−	−−	−	+	+
[4.3 e]	Systems (internal)	−	−−	−−	−	−	++	++
[4.4 e]	Technology (internal)	−−	−−	−−	−	−	−−	+
[4.5 e]	Time (internal)	−	−−	−−	−−	+	−	++
[4.6]	General depiction of customer perceived quality	−	++	−−	−−	−	−−	−
[4.6.1]	Outcome (technical) quality	−	+	−	−−	−	−−	−
[4.6.2]	Process (functional) quality	+	+	−−	−−	−	−−	+
[4.7]	Quantitative service output	−	−	−	−−	+	−−	+
[4.8]	Demand (and capacity utilization) aspects	−	+	+	−−	+	−−	−

intermediaries, *stakeholders*, *consumer* and *targetConsumers*. The module *Pricing* can be used to model a range of economic indicators for a service, e.g., tariffs, prices, or discounts. The construct *dependencies* would allow for modeling a pre-combination; however, it is clearly intended for modeling dependencies between services in a service bundle and not in the way Corsten (1994) or Grönroos and Ojasalo (2004) had proposed. USDL provides no dedicated constructs to model the results or output of a service. Instead, the module Service Level provides *GuarantedAction* to describe the outcome and its level of quality. However, opposing Vuorinen et al. (1998), this construct is focused on tangible outputs, just like the construct *Customer Satisfaction*.

The evaluation suggests that USDL focuses on the development and discovery of services, comprising business services and technical services. Although it is the most comprehensive CMG evaluated in this paper, it still lacks crucial modeling constructs needed for service productivity management.

4.6 eEPC and BPMN

Apart from the domain-specific CMGs discussed in the preceding sections, the Extended Event Driven Process Chain (eEPC) and the Business Process Model and Notation (BPMN) are modeling grammars for business processes that can be used irrespectively of particular domains. EPCs model processes with a control flow, i.e., in a series of sequences in a business context. EPCs are bipartite, directed graphs, comprising the basic elements *Function*, *Event*, and *Connector*. The eEPC is extended with additional elements, such as business organizational units and data objects. eEPC is embedded into the ARIS modeling framework, interconnecting different views on the organization (Scheer 1998, 2000). BPMN is a graphical representation of business processes or workflows in a process model. We refrain from presenting the extensive meta model here and refer to the literature (Object Management Group 2011).

One major drawback of both CMGs is their lack of constructs to measure quantities, e.g., resources, goods, or human input. For the eEPC this holds true for qualitative inputs and outputs, too. It follows that most evaluation criteria cannot be met. Customers' feedback cannot be modeled with a specific construct. There are modeling constructs for *Information* and *Systems*, allowing the modeler to specify information to be shared between service providers and consumers. The pre-combination and end-combination of services can be modeled on a business process level. The achievement potential can be only implicitly modeled as a part of the service process in which the customer is not involved as an organizational unit. The eEPC can specify activities with and without a customer by utilizing the constructs *Person Intern* and *Person Extern* (Table 7).

BPMN lacks constructs for modeling quantities of inputs or outputs. Shared information and shared sub-processes can be modeled with *Swim Lanes*. Due to BPMN's focus on IT-environments, physical resources can only be modeled as *Systems* which are amended by *Databases* and *Messages* to model an information exchange. A pre-combination and end-combination can be modeled by using *Event Sub-Processes* for either phase. BPMN includes *Timer Events* to account for interrupting events that can be adapted to measure the chronological length of a service process in order to specify time as an input factor in the service process.

5 Discussion

Our analysis of the ontological expressiveness of selected CMGs in the light of seminal theories on service productivity management contributes to mapping the current support for conceptual modeling in this area in three respects.

First, the analysis documents that none of the identified CMGs was designed with the intention of measuring service productivity in the first place. The CMGs that have not been designed particularly for the service sector, such as eEPC and BPMN, lack the domain-specific modeling constructs that are required for managing service productivity. Even if some of these constructs could be emulated with general-purpose constructs such as annotations, the resulting models would still be unspecific and difficult to interpret by humans and by machines. Some of the CMGs designed for modeling service phenomena—H2-ServPay, the e^{3}family, SNN, Molecular Model, and USDL—cover parts of the evaluation criteria reasonably well. However, even the most complete CMG USDL suffers from a lack of constructs for modeling service productivity. We conclude that, interestingly, service productivity management has remained largely unaddressed by CMGs. One explanation might be that the description, configuration, and pricing of services are more pressing issues for bringing new services to market, whereas productivity management is a second step that is carried out for assessing the efficiency of services in the market. Therefore, CMGs for service productivity management might just leg behind CMGs for service engineering. The result is that none of the currently available CMGs can be used as-is for this purpose. In order to develop more complete CMGs, the meta models of these approaches need to be joined or extended with additional constructs, as documented by Becker et al. (2012).

Second, it is obvious that the analyzed CMGs differ in terms of the focused units of analysis in a service system. Both the BPMN and the eEPC were designed to model business processes, whereas H2-ServPay, the e^{3}family, SNN, USDL, and the Molecular Model were developed to model the structural properties of modular services as sales objects that can be designed, traded, and consumed. Consequently, both BPMN and eEPC do not offer the modeling constructs required for depicting the resources that are consumed in service processes. This includes the inputs required to provide the services, and the outputs as results of consuming a service. However, if the modeled processes were instantiated in a workflow management system, the workflow engine itself might be able to document process execution times, even if the CMGs itself do not provide the required modeling constructs. This suggests that it might not be enough to analyze CMGs solely for their ontological expressiveness. Additionally, analyses of modeling tools and runtime environments into which those CMGs are embedded might have to be performed in order to draw a complete picture.

Third, the lack of CMGs for service productivity management is contrasted by an abundance of CMGs that overlap each other without being compatible enough to create a consistent portfolio of CMGs. Barros and Oberle (2012) mourn that there is still a misalignment between techniques for modeling business services and technical services. Our analysis demonstrates that this is even so amongst CMGs for business modeling. In order to develop a consistent array of CMGs, we propose a service modeling stack by building on the work of Kohlborn and la Rosa (2012) as well as Danylevych et al. (2010), Fig. 11. The modeling stack systematizes approaches for service modeling, starting from modeling portfolios of business services and customer needs. In a top-down process, service instances can be configured based on this information, defining offerings and business processes in the service system. If any business service would be provided as a technical service (e.g., as a web service) or require a technical service in order to be provided, approaches for modeling technical services must be aligned with approaches for modeling business services. On the other hand, technical services could be brought to market by offering them as value propositions on electronic marketplaces, referred to as bottom-up approach in Fig. 11. We argue that modeling constructs for

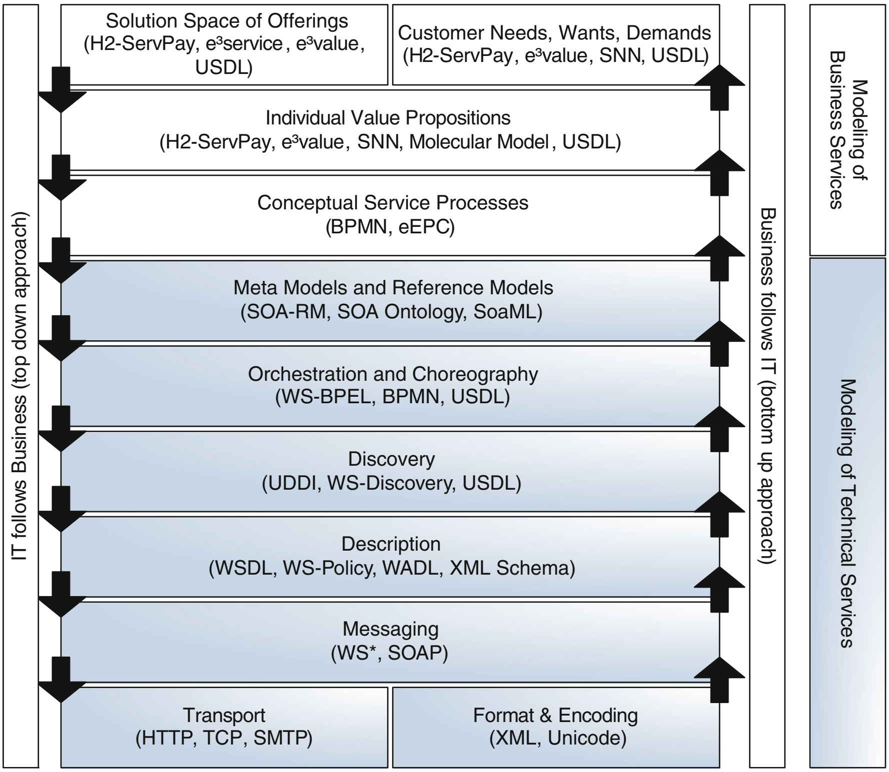

Fig. 11 Service modeling stack, developed building on Danylevych et al. (2010) and Kohlborn and la Rosa (2012)

enabling service productivity management—such as the ones proposed in this study—must be present at each layer to allow for a the conceptualization, measurement, and management of service productivity.

6 Conclusion

In this paper, we evaluated the ontological expressiveness of CMGs to support service productivity management. It was shown that none of the analyzed CMGs was complete in modeling all aspects required for service productivity management. Since the set of CMGs analyzed was compiled based on reviewing a set of comparative studies, we are confident that no more adequate CMGs were excluded. This finding highlights the need to design more adequate CMGs for service productivity management in the future. Options would be to add language constructs to the meta models of existing CMGs or to develop an additional CMG.

Although we do not claim that this assessment is invulnerable to subjectivity, we argue that our approach is sufficient to offer a general appraisal of a CMG's ontological expressiveness. We took precautions to limit bias resulting from subjective assessments by evaluating the CMGs separately, and resolving inconsistent ratings in a follow-up discussion process. Most of the disagreement could be traced back to modeling constructs that were arguably missing in the CMG, but could be emulated in some way by applying general-purpose constructs such as annotations in the model. In these cases, the intermediate rating levels '+' and '–' were assigned.

Concerning the analysis of CMGs, authoritative literature on conceptual modeling holds much potential to guide further investigations. Wand and Weber (2002) identify three additional types of grammatical deficiencies, as well as point to the importance of evaluating and designing modeling methods, modeling scripts, and modeling contexts. Recker et al. (2011) examine the impact of grammatical deficiencies on the perceived usefulness of modeling grammars. Such an investigation is promising for service productivity management in order to investigate if the identified deficiencies really matter for companies. Burton-Jones et al. (2009) develop four guidelines for empirical evaluations of CMGs that could complete this picture.

With respect to service productivity theories, future research shall strive to develop a complete ontology for service productivity management. As a first step, we provided a collection of constructs based on reviewing service productivity theories. However, literature on operations research methods for productivity analysis contains many other constructs that do not seem to have found their way into current productivity theories. For instance, exhaustive literature on the Data Envelopment Analysis (DEA) emphasizes the need to account for *Discretionary Factors*—such as environmental factors—that might impair productivity but cannot be actively managed by service companies (Muniz et al. 2006; Ruggiero 1998).

Acknowledgments The German Federal Ministry of Education and Research (BMBF) funded this work in the scope of the research project ServDEA, promotion sign 01FL10015. In addition, we gratefully acknowledge the support provided by the project management agency German Aerospace Center (PT-DLR). Furthermore, we wish to thank the reviewers for their constructive and helpful comments to the final article.

References

Bardhan IR, Demirkan H, Kannan PK, Kauffman RJ, Sougstad R (2010) An interdisciplinary perspective on IT Services Management and Service Science. JMIS 26(4):13–64

Barros A, Oberle D (2012) Handbook of service description. Springer, New York

Becker J, Beverungen D, Knackstedt R, Müller O (2009a) Model-based decision support for the customer-specific configuration of value bundles. EMISA 4(1):26–38

Becker J, Knackstedt R, Beverungen D, Bräuer S, Bruning D, Christoph D, Greving S, Jorch D, Joßbächer F, Jostmeier H, Wiethoff S, Yeboah A (2009b) Modellierung der hybriden Wertschöpfung: Eine Vergleichsstudie zu Modellierungstechniken. In: Arbeitsberichte des Instituts für Wirtschaftsinformatik, Nr. 125. WWU Münster

Becker J, Beverungen D, Knackstedt R (2012) A method for selectively designing modeling languages for product-service systems. In: Dolk D, Granat J (eds) Lecture Notes in Business Information Processing (LNBIP). No. 42: Modeling for decision support in network-based services: the application of quantitative modeling to service science, 1st edn. Springer, Berlin, pp 87–117

Bergamaschi S, Beneventano D, Guerra F, Orsini M (2011) Data integration. In: Embley D, Thalheim B (eds) Handbook of conceptual modeling: theory, practice, and research challenges. Springer, New York, pp 441–476

Birkmeier DQ, Overhage S, Schlauderer S, Turowski K (2012) How complete is the USDL? A theoretical evaluation of its capability to specify software services. In: Oberle D, Barros A (eds) Handbook of service description. Springer, New York, pp 509–526
Brown R (2006) Mismanagement or mismeasurement? Pitfalls and protocols for DEA studies in the financial services sector. Eur J Oper Res 174(2):1100–1116
Burton-Jones A, Wand Y, Weber R (2009) Guidelines for empirical evaluations of conceptual modeling grammars. JAIS 10(6):495–532
Chen PPS (1976) The entity-relationship model—toward a unified view of data. ACM Trans Database Syst 1(1):9–36
Corsten H (1994) Diskussionsbeiträge der Wirtschaftswissenschaftlichen Fakultät Ingolstadt Überlegungen zum Produktivitätsmanagement für Dienstleistungsunternehmen—dargestellt am Beispiel bilateraler personenbezogener Dienstleistungen. Katholische Universität Eichstätt-Ingolstadt, Ingolstadt
Danylevych O, Karastoyanova D, Leymann F (2010) Service networks modelling: an SOA & BPM standpoint. J Univers Comp Sci 16(13):1668–1693
De Kinderen S (2010) Needs-driven service bundling in a multi-supplier setting: the computational e3service approach. Free University, Amsterdam
Emrouznejad A, De Witte K (2010) COOPER-framework: a unified process for non-parametric projects. Eur J Oper Res 207(3):1573–1586
Ferrario R, Guarino N, Trampus R, Laskey K, Hartman A, Gangadharan G (2012) Service system approaches—conceptual modeling approaches for service science. In: Barros A, Oberle D (eds) Handbook of service description. Springer, New York, pp 75–109
Gordijn J, Akkermans H (2001) e3-Value: design and evaluation of e-business models. IEEE Intell Syst 16(4):11–17
Grönroos C, Ojasalo K (2004) Service productivity—towards a conceptualization of the transformation of inputs into economic results in services. J Bus Res 57(4):414–423
Hevner AR, March ST, Park J, Ram S (2004) Design science in information systems. MISQ 28(1):75–105
Heymans S, Hoffmann J, Marconi A, Phillips J, Weber I (2012) Semantic web fundamentals. In: Barros A, Oberle D (eds) Handbook of service description. Springer, New York, pp 135–158
Juhrisch M (2010) Richtlinien für die modellgetriebene Integration serviceorientierter Architekturen in Analysemodellen. Dissertation, TU Dresden
Käpylä J, Jääskeläinen A, Lönnqvist A (2010) Identifying future challenges for productivity research: evidence from Finland. Int J Prod Perform Manag 59(7):607–623
Kohlborn T, La Rosa M (2012) SOA approaches. In: Barros A, Oberle D (eds) Handbook of service description. Springer, New York, pp 111–133
Kuechler B, Vaishnavi V (2008) On theory development in design science research. EJIS 17(5):489–504
Linna P, Pekkola S, Ukko J, Melkas H (2010) Defining and measuring productivity in the public sector: managerial perceptions. Int J Public Sec Manag 23(5):479–499
Muniz M, Paradi J, Ruggiero J, Yang Z (2006) Evaluating alternative DEA models used to control for non-discretionary inputs. Comput Oper Res 33(5):1173–1183
Nachum L (1999) Measurement of productivity of professional services. JOPM 19(9):922–949
Oberle D (2012) D1 report on landscapes of existing service description efforts. http://www.w3.org/2005/Incubator/usdl/wiki/D1. 19 Dec 2012
Object Management Group (2011) Business process model and notation (BPMN) version 2.0
OECD (2005) Enhancing the performance of the services sector. OECD Publications, Paris
Parasuraman A (2002) Service quality and productivity—a synergistic perspective. Manag Serv Qual 12(1):6–9
Pedrinaci C, Maleshkova M, Zaremba M, Panahiazar M (2012) Semantic web services approaches. In: Barros A, Oberle D (eds) Handbook of service description. Springer, New York, pp 159–183
Razo-Zapata I, De Leenheer P, Gordijn J, Akkermans H (2011) Service value networks for competency-driven educational services: a case study. In: Proceedings of the 6th international BUSITAL workshop, pp 81–92, London
Razo-Zapata I, De Leenheer P, Gordijn J, Akkermans H (2012) Service network approaches. In: Barros A, Oberle D (eds) Handbook of service description. Springer, New York, pp 45–74
Recker J, Rosemann M, Green P, Indulska M (2011) Do ontological deficiencies in modeling grammars matter? MISQ 35(1):57–79
Ruggiero J (1998) Non-discretionary inputs in data envelopment analysis. Eur J Oper Res 111(3): 461–469

Rust RT, Huang M (2012) Optimizing service productivity. J Mark 76(2):47–66
SAP Research (2009) USDL specifications. http://www.internet-of-services.com/index.php?id=54. 25 Mar 2012
SAP Research (2011) Unified service description language 3.0 (USDL) overview
Scheer A-W (1998) Business process engineering. Reference models for industrial enterprises, 1st edn. Springer, Berlin
Scheer A-W (2000) ARIS—business process modeling, 3rd edn. Springer, Berlin
Schrader U, Hennig-Thurau T (2009) VHB-JOURQUAL2: method, results, and implications of the German Academic Association for Business Research's Journal Ranking. Bus Res 2(2):180–204
Shostack GL (1977) Breaking free from product marketing. J Mark 41(2):73–80
Shostack GL (1982) How to design a service. Eur J Mark 16(1):49–63
Siau K, Rossi M (2011) Evaluation techniques for systems analysis and design modelling methods—a review and comparative analysis. Inf Syst J 21(3):249–268
Vargo SL, Lusch RF (2007) Service-dominant logic: continuing the evolution. J Acad Mark Sci 36(1):1–10
Vuorinen I, Järvinen R, Lehtinen U (1998) Content and measurement of productivity in the service sector: a conceptual analysis with an illustrative case from the insurance business. Int J Serv Ind Manag 9(4):377–396
Wand Y, Weber R (2002) Research commentary: information systems and conceptual modeling—a research agenda. ISR 13(4):363–376
Webster J, Watson RT (2002) Analyzing the past to prepare for the future. MISQ 26(2):13–23
Wierenga B (2012) The past, the present and the future of marketing decision models. In: Wierenga B (ed) Handbook of marketing decision models. Springer, New York, pp 3–23
Zeithaml VA, Parasuraman A, Berry LL (1985) Problems and strategies in services marketing. J Mark 49(2):33–46