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Construction of Productivity Models

A Tool-Supported Approach in the Area of Facility Management

Productivity models specify input and output factors to inform productivity analyses. Current research and business practice face the challenge of developing a wide range of different productivity models. These models were created simultaneously but isolated from each other. As a consequence thereof, several practices of productivity model construction have emerged. This paper presents a unifying modelling language that lists and interrelates the essential constructs, pertinent to productivity models. Ultimately it was transferred into practice by employing a software tool. The application was conducted in the area of facility management, supporting two different approaches of productivity benchmarking. Facility management features a huge diversity of offered services and bundles. Thus, facility managers cope with various definitions of productivity that are then modelled with our approach.

1 Productivity Models

The concept of productivity has – in past and present – played a unique role in the self-conception of organisations (Coelli et al. 2005; Deming 1982). Defined as the relation of productivity factors – output to input (Farrell 1957) – the term traditionally refers to the production of physical products (Corsten and Gössinger 2003). For instance, at the level of a single production unit, in addition to being accounted in monetary units, inputs can be measured in weights or volumes of raw or semi-finished materials. Hence, outputs are the by-product and the finished product. As such productivity is tracked as sets of partial productivity, such as, e.g., labour productivity (Corsten and Gössinger 2003). Concerning the productivity of services, these concepts seem to be limited due to the nature of service production processes as open systems and the participation of customers in those processes (Grönroos and Ojasalo 2004).

Productivity has received a lot of attention from various economic perspectives, especially with regard to measuring performance in services (Daveri and Jona-Lasinio 2008; Drucker 2010; Nesta 2008; Wagner 2010). Compared to goods, services exhibit specific characteristics, which complicate the simple adaptation of the goods-related concept of productivity as an output-input-relationship (Baumgärtner and Bienzeisler 2006; Lasshof 2006). Classic examples for this challenge are the intangibility, the heterogeneity, the inseparability of production and consumption, and the perishability of services (Lovelock and Gummesson 2004; Zeithaml et al. 1985). One aspect being focal for this article is the so-called multi-factor-productivity of service operations. Service processes not only feature multiple resources – inputs – that are deployed, but also numerous outputs as the result of service provision (e.g., changes in customer satisfaction, increased revenue etc.) (Grönroos and Ojasalo 2004).

Today a bewildering variety of approaches are on hand to transfer the concept of productivity to services. However, it seems unlikely that a single concept of productivity could evolve to accommodate all types of services and their environmental conditions (such as availability of data, incentive systems etc.). Instead, numerous sources name a multitude of heterogeneous requirements and solutions (Corsten and Gössinger 2003; Grönroos and Ojasalo 2004; Lovelock and Gummesson 2004; Parasuraman 2010; Vuorinen et al. 1998). It seems much more likely that a number of variants of service productivity concepts will evolve which will only be applicable to specific constellations. If this assessment is correct, it will be one task of enterprise modelling theory to analyse the construction of applicable production models and to develop suitable methods and tools, which support the construction process. The latter form the basis for the development of suitable productivity models that fit to the specific situations and emerge from key requirements in diverse scenarios.

Since the establishment of service engineering as a distinct discipline (Fähnrich and Meiren 2007), a great number of languages for modelling services has emerged. Many of these approach services (a) from a structural view – describing them as a composite of individual performance components – or (b) from a process-based view, focusing on the process of service delivery. However, there are some model architectures that cover both aspects (Klein 2007). Furthermore, the approaches differ according to whether they are uniquely applicable to services and/or also to production (for a detailed overview, see, e.g., Becker et al. 2009). These model types, however, are not ideally suited to create a workable understanding of productivity as a construct of measuring the performance of a single service instance (Becker et al. 2012b). Especially, those models that allow for a meaningful selection and an exact specification of multiple input- and output-factors of a specific productivity concept cover the whole complexity of service productivity benchmarking. In particular these models will be referred to as productivity models in the following sections.

This paper examines which information structure has to be used to specify the productivity of goods and services. Therefore, a modelling language is developed, that supports the construction of productivity models. This language establishes the essential structural characteristics of productivity models and their relationships and is implemented in a dedicated modelling software.

The article is structured as follows: Based on a literature review, an overview is given to depict the existing approaches of creating service productivity models. The most advantageous traits of these concepts are be deduced to form modelling requirements (Sect. 2). Building on this, relevant requirements are be explicated and integrated in our modelling approach. It is particularly documented in a meta-model and implemented in a modelling tool (Sect. 3). To test its applicability, the modelling language are exemplarily be applied to measure services productivity in the field of facility management (Sect. 4). The discussion of this evaluation reveals the variety of relevant conceptualisations of service productivity in terms of both value and quantity. This necessitates the development of generic support of construction processes of productivity models by methods, languages and tools. The diversity of variants supports our hypothesis that services modelling – in addition to the prevalent structural and process-based models – should attend to the construction of productivity models. Furthermore, the application of the modelling language makes an important contribution to create productivity models for practical plausibility. Finally, the article gives a forecast to future activities and a discussion of potentials for development (Sect. 5).

2 Related Work to the Construction of Productivity Models

Productivity models describe the specifications of input and output factors to being used in a productivity analysis. In the education sector the term is used for analyses measuring the impact of the provided resources on the learning outcome in a broader sense (Haertel and Walberg 1980). For instance, the input-environment-output (I-E-O) model explains the learners' perception in terms of input factors like working hours, capital, or physical resources by means of regression analysis. The explained variables – the outputs – are outcome clusters such as cognitive skills, knowledge acquisition and practical competence (Astin 2002). Recently, this concept has been used to develop a graphic representation of a productivity model (Bitzer et al. 2010). To measure productivity in the field of adult education service, the authors created a productivity model. They named and compiled the relevant factors but hesitated to develop a specific syntax or a meta-model. However, the authors – obviously inspired by Grönroos and Ojasalo (2004) – attributed input factors to certain actors of the underlying service process (e.g., some inputs were introduced by the teachers, others by the pupils).

In the area of company-wide productivity accounts, productivity models adapt economic accounting models (Saari 2006). This model follows a parameterised approach, which makes the determination of costs for each and every input or output factor necessary and limits the comparability of organisations, as costs may vary and are hard to define across the board. The productivity of the software development process has been examined by means of regression analyses to forecast the output factors “time” and “cost” (Jeffery 1987). In this area it was evidenced that different productivity models apply for different branches (Maxwell and Forselius 2000). For instance, the factor “complexity of interface” is the most decisive factor of influence on productivity of software development for the financial sector. Concerning software development for the manufacturing industry, the underlying “hardware platform” is much more influential with respect to productivity.

The aforementioned approaches have either not been quantified at all or by means of regression analyses. This contrasts with the econometric, non-parametric method of data envelopment analysis (DEA). The main advantage of this method is the ability to process a large quantity of inputs and outputs for a given productivity model. In addition, DEA allows for an incorporation of economies of scale. To do so, DEA compares units under analysis with respect to their size, e.g., service teams are benchmarked in terms of their headcount (Cullinane et al. 2006). One major drawback of DEA is the substantial effect of model misspecifications and the inclusion or exclusion of variables (Corton and Berg 2009). For this reason, to describe the set of applied variables, productivity models are also drawn upon (Avkiran 2002). Each productivity factor is described by an indicator which quantifies the factor (Avkiran 2002). For example the factor “interest-related payments” is quantified by “the sum of salaries, pensions etc.” Thus, a two-tier specification is introduced, which additionally lists the factors and quantifies them. This procedure contributes to improve the replicability of the study findings and to structure the model appropriately.

Concerning the selection of factors for a productivity model Dyson, Allen, Camanho, Podinovski, Sarrico and Shale recommend that inputs and outputs should cover the full range of resources used and the targets aimed for as well as the produced outputs (Dyson et al. 2001). This might be achieved by a careful consideration of the consistency of the mission, objectives and performance measures (Dyson et al. 2001). Furthermore, the authors elaborate on a concept that is unique to DEA: exogenous variables. Although, such variables have significant influence to productivity, they cannot be changed or influenced by the unit under analysis. They encompass environmental conditions, and geographical or regulatory factors. Such circumstances have to be identified to clearly point out the true sources of inefficiency (Ruggiero 1998).

The literature on DEA has already yielded a variety of diverse approaches to the construction of productivity models. One of the better known DEA procedures is the COOPER model (Emrouznejad and De Witte 2010). This approach recommends a fundamental literature-based analysis, by interviewing either the objects of investigation – if possible – or experts from the field. These analyses can then be supported by multivariate data analyses. In addition, the course of a DEA-based productivity analysis is structured in a sequence of activities. This facilitates performance assessment and helps to translate the aim of the performance measurement to an appropriate input/output selection (Emrouznejad and De Witte 2010). However, Emrouznejad and De Witte propose a process for operational research-based benchmarking projects. They rather address general aspects as well as data quality issues and method selection. They allocate only a fraction of their process to the information structure that covers inputs and outputs – the productivity model.

Although various areas of research have made contributions regarding productivity models, a generally accepted form of description has not crystallised, yet. Thus, we summarise the most advantageous traits of the presented approaches below in the form of requirements. These will found the basis to ultimately offer a consistent modelling language of productivity models:

- Productivity models are used in a number of domains. These include education, but being not limited to (Haertel and Walberg 1980) and software engineering (Maxwell and Forselius 2000). They are particularly useful, if it is difficult to valuate productivity factors with cost rates or other variables. Hence, if it is not possible to find a common comparative dimension for inputs and outputs, productivity models are employed. Consequently, a productivity modelling language must allow for the definition of various productivity models (R1).
- Wherever productivity models are used, input factors are compared with output factors (Grönroos and Ojasalo 2004). To reflect the concept of multi-factor productivity (Saari 2006), each productivity model should feature multiple input- and multiple output-factors (R2).
- Some input-factors can only be influenced by some actors of a service process (Dyson et al. 2001; Grönroos and Ojasalo 2004). When modelling productivity this has to be accounted for (R3).
- In some areas of application, exogenous variables have – in addition to input and output factors – also proved helpful in objectifying productivity (Dyson et al. 2001). Hence, this concept should be incorporated (R4).
- Multi-level concepts for structuring productivity models support the modelling process (Emrouznejad and De Witte 2010). A model should be separated into layers of decreasing complexity to structure the construction process (R5).
- The mission of the productivity measurement project (Emrouznejad and De Witte 2010) and the environment of a productivity model should be captured in a model. For instance, the industry (e.g., finance, education and software engineering), and the region have each a crucial effect on the productivity of benchmarked units (R6).
- In each of the surveyed cases, productivity models form a preliminary conceptual stage to ultimately allow for the calculation of a productivity ratio (Avkiran 2007). Thus, the quantification of input- and output-factors should be provided as clear and replicable as possible to facilitate the employment of different calculation methods (R7).

3 A Modelling Language for Productivity Models

In this section, we implement the previously mentioned requirements by incrementally deducing a modelling language for productivity models. First, we identify and define modelling constructs and their graphical representations from the requirements (Tab. 1). We then unite the constructs and their interrelations in a meta model for productivity models (Fig. 1). Finally, we create a modelling editor to support the construction of productivity models by employing the meta modelling tool H2 with our modelling language (Backhaus et al. 2010; Becker et al. 2009, 2011c; Delfmann et al. 2006).

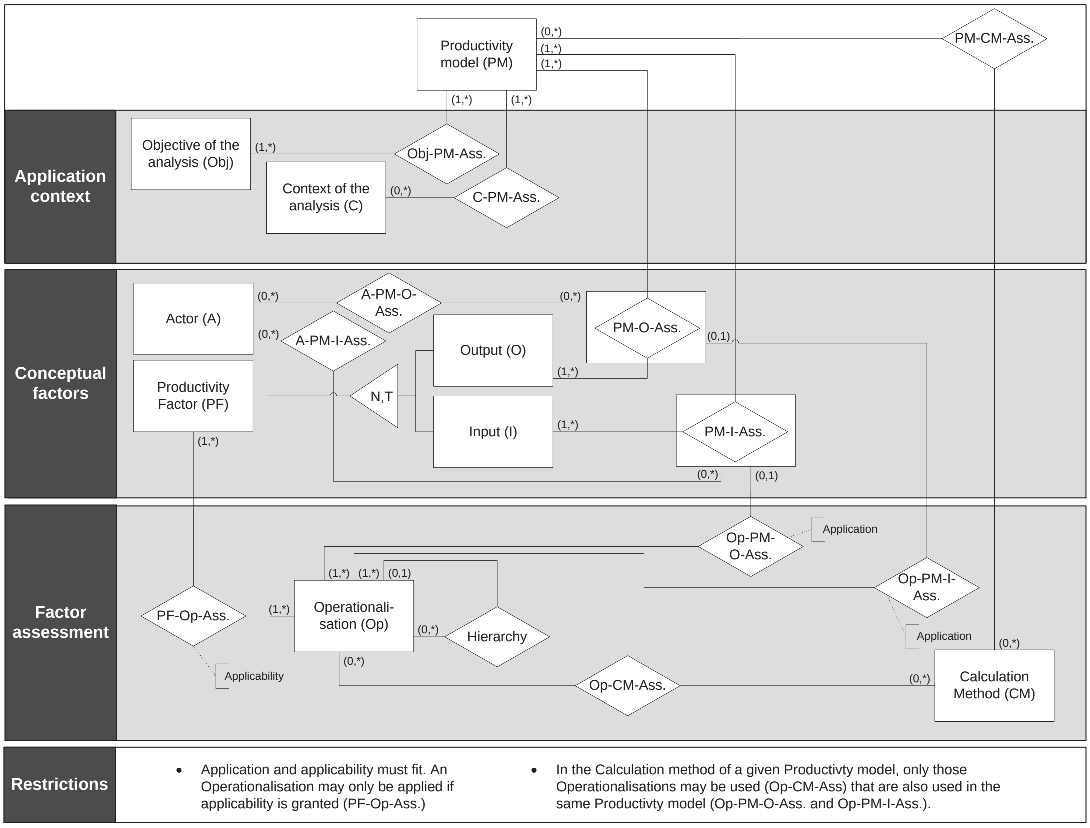
As a first step, constructs along with their graphical representations are introduced (Tab. 1) to implement the requirements of the previous section. Subsequently, constructs are referred to in italics.

- To account for requirement R1, the construct *Productivity model* is introduced to form a basic structure that interconnects the different concepts in productivity analysis.
- To fulfil R2 we introduce the construct *Productivity factor*. It represents either consumed resources (inputs) or goals of an organisation that are attained (outputs). Thus, we attribute the construct as an abstract concept which is then specialised by *Inputs and Outputs*.
- Every *Input* must be allocated to a party that contributes to the underlying resource. To mark this entity, the construct *Actor* is introduced (R3).
- The introduction of a dedicated construct to represent exogenous variables (R4) is not necessary. Instead, to capture this aspect, some *Productivity factors* can be associated with the construct *Actor*. Hence, the *Actor* can be instantiated as follows. On the one hand a productivity factor can be influenced by a provider (e.g., staffing of a service unit) or a customer (e.g., pupils that are participating in coursework, or employees of a customer that are creating a detailed requirements specification for a software project). On the other hand, there are factors that only can be attributed to external, detached parties. For instance in the assessment of teachers, the pupils' parents' educational background plays a significant role (Astin 2002). As the background of pupils cannot be influenced by either teacher or pupil, this factor 'background' is declared as an exogenous factor. Thus, the *Actor* to this factor is instantiated as exogenous. Thereby this relation fulfils (R4).
- To meet R5, the meta-model on hand is structured into three layers: *Application context*, *Conceptual factors*, and *Factor assessment*. They are visually separated to facilitate the distinction between the layers.
- To reflect the mission of a productivity-measurement project and its organisational environment, the two constructs *Objective of the analysis* and *Context of the analysis* are introduced (R6).
- To provide a basis for the quantification of *Productivity factors* without preordaining the method of analysis, so-called *Operationalisations* are introduced together with the *Calculation method* (R7).

The constructs from Tab. 1 are interconnected by explicating the type of their relation. To achieve this, we denote the constructs' relationships in terms of entity types and relationship types in entity-relationship-models (Chen 1976) (Fig. 1). This notation is still one of the most dominant and wide-spread modelling techniques (Fettke 2009).

The development of a *Productivity model* is usually initiated with the definition of the project's objectives and its context. Both are expressed by the constructs in the top layer, the *Application context*. This urges the modeller to explicate the *Objective of the analysis* clearly. It must reflect the context and environment of the analysis to reveal the underlying conditions. Depending on the field, previously set criteria (e.g., line of business, organisational level etc.) may be employed here. In the meta-model, this is accounted for by the constructs *Objective of the analysis* and *Context of analysis*. These constructs define the productivity model at the top level. At the same time, the explication of the whole *Application context* facilitates the reuse of once assembled productivity models in similar scenarios later on.

In order to concretise the rather abstract constructs from the layer *Application context*, the



- Application and applicability must fit. An Operationalisation may only be applied if applicability is granted (PF-Op-Ass.)
- In the Calculation method of a given Productivty model, only those Operationalisations may be used (Op-CM-Ass) that are also used in the same Productivty model (Op-PM-O-Ass. and Op-PM-I-Ass.).

Figure 1: Simplified meta-model

Table 1: Allocation of requirements to constructs.

Requirement	Constructs introduced	Graphical representation in H2
R1	Productivity model	⇄
R2	Productivity factor Input Output	(no representation) ⬇ ⬆
R3	Actor	👤
R4	Covered by R3	-/-
R5	Structuring the model in three layers	Application context Conceptual factors Factor assessment
R6	Objective of the analysis Context of the analysis	◎ 🌐
R7	Operationalisation Calculation method	🔧 📈

objectives are substantiated in the middle layer – the *Conceptual factors*. This layer is characterised by the allocation of productivity factors to the layer-spanning construct *Productivity model*. In this layer, *Inputs* and *Outputs* can be non-disjunctively differentiated. At least one of each is necessary to form a valid and complete *Productivity model*. However, both constructs inherit from the abstract generalisation *Productivity factor*.

Every *Productivity factor* is allocated to *Actors*. This reflects how inputs are contributed by the different parties that are involved in the process of service provision (e.g., customers, the service provider). In addition, the concept *Actor* also enables a modeller to declare some *Productivity factors* – *Inputs* or *Outputs* – as exogenous. To ensure reusability across different *Productivity models*, the relation of a *Output* or an *Input* to an *Actor* is determined by the *Productivity model* through the associations A-PM-O/A-PM-I and PM-O-Ass./PM-I-Ass. Thus, the allocation of *Actors* to *Productivity factors* depends on the underlying *Productivity model*.

With the help of hierarchically aggregated *Operationalisations* a model can be computed by using one or several different *Calculation methods*. Instances for this construct are DEA, regression analysis or its adaptions (e.g., stochastic frontier analysis (Cullinane et al. 2006)) or other parametric methods mentioned in the preceding chapter. However, as each *Operationalisation* has its own, unique relation to the *Productivity model*, the construct also supports basic arithmetic operations per *Operationalisation* to ensure methodological flexibility. The construct *Calculation method* also covers method-specific information which cannot be modelled here. We want to keep the model as neutral – with respect to the calculation method applied – as possible. Therefore, we have refrained from including further mathematical detail for the allocation of calculations in Fig. 1 and in Fig. 2.

The relationship between an *Operationalisation* and the superordinate constructs *Productivity factor* and its specialisations is characterised as follows: On the one hand the relation between a given *Productivity factor* and a given *Operationalisation* can be feasible. Then it is applicable. On the other hand, whether this relationship is in fact implemented in a given *Productivity model* is documented in the other association, the application. To ensure internal consistency, a relationship can only be applied if it is also applicable. Therefore, the following restrictions must be taken into account:

- The associations Op-PM-O/Op-PM-I restrict the use of a given *Operationalisation* in a *Calculation method* (Op-CM-Ass.) to those *Operationalisations* that are also used in the same *Productivity model* (Op-PM-O/Op-PM-I). We denote these associations as “application” as they depict whether an *Operationalisation* is correctly employed.
- The restriction “applicability” denotes that application and applicability of an *Operationalisation* must fit. Any *Operationalisation* may only be applied – as mentioned before – if applicability is granted (PF-Op-Ass.).

Although not being covered in Fig. 1, both restrictions have to be enforced. This can be implemented in software application logic or by employing database constraints.

Our language is implemented in the meta modelling language editor H2 as depicted in Fig. 2. The H2-editor that was used to design the language is separated into two areas: In Fig. 2 the left pane (*Objekttypen*, object types) features single constructs of the modelling language and the right pane (*Kontexte*, contexts) describes their hierarchical interrelations in different contexts (Backhaus et al. 2010; Delfmann et al. 2006). Only object types that are associated to other object types within contexts are placed in a hierarchical relationship.

To implement the described modelling language, the modelling editor H2 uses building blocks, so-called contexts (*Productivity models* and *Productivity factors* respectively) that can be reused in subsequent modelling projects. The lower three H2-contexts *Application context*, *Conceptual factors*, and *Factor assessment* depict the layer-wise structuring of the *Productivity model*. Each layer restricts the visible constructs to render only those constructs visible that are in process for that layer.

In the following, the applicability of the modelling-language for the development of context-specific services productivity models will be demonstrated by an exemplary application in the area of facility management.

4 Productivity Models in Facility Management

4.1 Characterisation of Facility Management

The branch of facility management (FM) has grown significantly in recent years and has become one of the most important employers in the

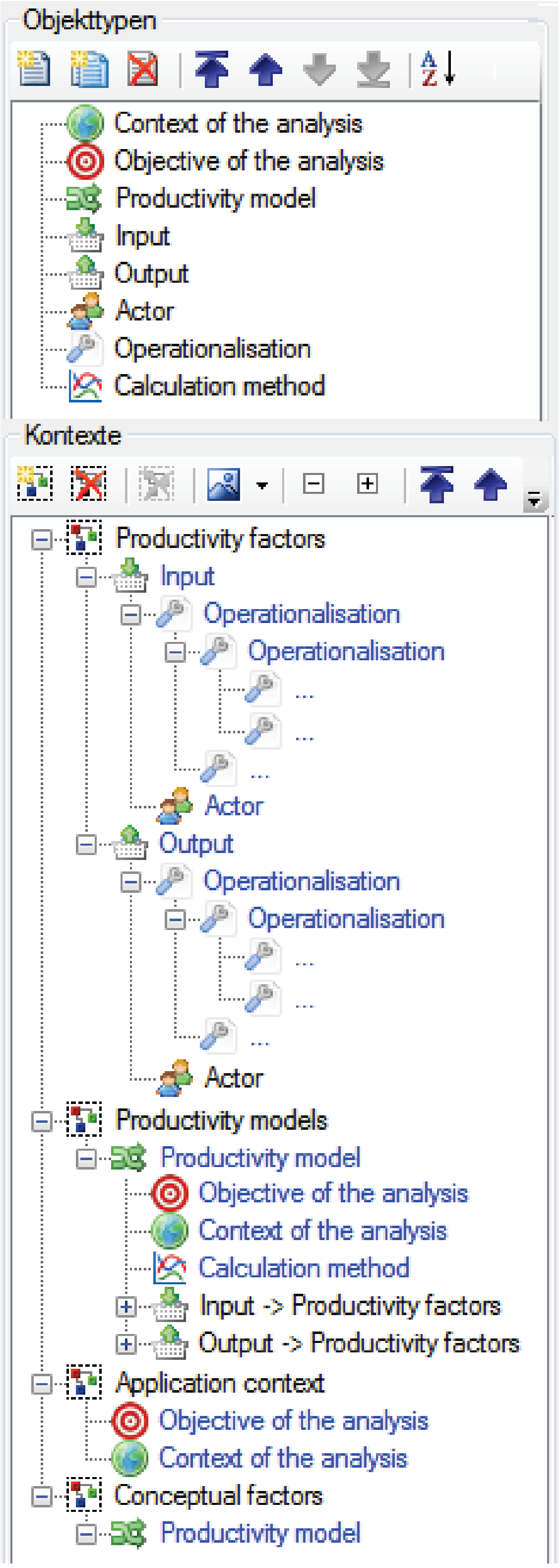


Figure 2: The modelling language in the H2 modelling editor

service sector (Amaratunga et al. 2000; McLennan 2004; Mudrak et al. 2004; Nutt 1999; Salonen 2004).

The concept of FM has been widely discussed in literature (Amaratunga et al. 2000; Kincaid 1994; Tay and Ooi 2001). Topics of discussion are the diversity of offered services, different service bundles and the resulting differences of staff competences (Bernhold 2010; Kincaid 1994; Tay and Ooi 2001), All national and international definitions agree that FM comprises the optimum operation of buildings and their technical equipment and the optimum support of the customer's core business with the aim to increase overall business performance (Amaratunga et al. 2000; GEFMA 2004; Kincaid 1994; Tay and Ooi 2001). Apart from reducing running costs, FM should also focus on increasing the efficiency of processes and work environments, combined with corresponding adaptations to user requirements (Amaratunga et al. 2000). Summarising the terminology of FM, it can be derived that FM has to be classified as secondary process with a strong focus on the physical infrastructure of companies as well as its user-related services (GEFMA 2004). Furthermore, FM should strategically be geared towards supporting the company's core business, while all activities should be informed by the property life cycle (Bernhold 2010).

All the services that are provided over a property's whole life cycle can be summarised under the term “FM services” (GEFMA 2004). Consequently, facility services form a sub-set of enterprise-related services, satisfying the needs of organisations (Bernhold 2010).

Facility services are provided by integrating the external factor which is temporarily placed at the service provider's disposal, but remains in the customer's possession (Bernhold 2010). The following productivity considerations focus on the facility services during a property's operational phase.

In particular the specific features of FM services can be examined by categorising them typologically. According to this kind of preliminary analysis, FM services can generally be separated into service shops or mass services. Taking into account their classifications, FM services show a distinct object focus which is marked by short customer contact periods. The services are largely provided outside customer business' hours, so that they have to be listed as back-office services, which are not delivered to the customer directly. Nevertheless facility services also have to be considered as integrative services in the sense that they include the customer's facilities as external factors in the service delivery process. Moreover, FM services tend to be less complex than services in general, because they need to be slightly adapted to specific customer requirements. Therefore, FM services in the building operations phase comply with high homogeneity in customer portfolios, which enables a general standardisation of facility services.

A decisive factor for contract compliance and customer satisfaction is the outcome in terms of a service product; the service process is generally not critically important for the customer. As opposed to general service features, facility services produce tangible outcomes, visible in changes in the service objects and they are highly site-specific, depending on the mobility of the customer's service objects.

The survey of the defining features of facility services clearly reveals that a productivity measurement of FM services should follow a modified approach to productivity because of the identified differences with services in general (Corsten 1994; Grönroos and Ojasalo 2004; Johnston and Jones 2004; Lasshof 2006). At the same time, the discussed FM features appear to be particularly suitable for productivity analyses and process optimisation, while knowledge-intensive services – frequently encountered in the capital goods industry – can rarely be adequately compared or optimised.

At present there is no general accepted definition of productivity in the FM area, although facility managers attach great importance to the necessity of service productivity evaluation (Bernhold et al. 2011). First attempts in measuring productivity of FM services are generally based on monetary factors that have not been developed exclusively for productivity assessments and mostly reflect the use of resources in relation to budgeted services (Bernhold et al. 2011). Existing quality measurements or customer satisfaction surveys for the measurement of service outcomes are usually separated from productivity assessments and are conducted in different systems. The reason for this is a lack of IT-systems for a global assessment of productivity. Frequently, current approaches of defining productivity measurements, are carried out by computing the parameters manually and then embedding them into proprietary system solutions (Bernhold et al. 2011). These solutions are, however, insufficient to produce a comprehensive picture of the stated productivity of facility services. Consequently, there is a general interest in alternative productivity models which consider all required productivity factors in one overall measurement system. This shows similar research gaps in measuring service productivity in managerial practice and current research: There is a general awareness of the need for service productivity measurements. However, neither a uniform definition of productivity nor a common system for productivity measurements is available. The lack of appropriate productivity models for the analysis of FM services warrants the development of such models.

In the following, the development of two productivity models based on our modelling approach are demonstrated. The model is distinguished in a productivity measurement in terms of value (i.e., monetary factors) and quantitative productivity measurement (i.e., volume, number) focusing on the collection of quantitative productivity indicators. The applicability of a variant depends on the given state of available performance information in the company. The monetary productivity measurement for example should be chosen in case of sparse performance information. Productivity measurements depending on quantitative terms facilitate a detailed analysis of service productivity and therefore, it should be used in companies with a wide range of data to assess input and output factors more specifically.

4.2 Measuring Productivity in Terms of Value

As depicted in Fig. 1, the productivity model to benchmark maintenance and cleaning services can be divided into three levels (Fig. 3):

At the top level, the *Application context*, the object of inquiry is described. In this case the productivity of facility services is measured by terms of value from a provider's perspective.

At the second level, the *Input and Output factors* need to be established in the given *Application context*. The input factors for the services provided consist of the primary input needed in the initial provision of a service and the additional input (secondary input) provided for contractual based improvements or goodwill services. In this context, service quality (qualitative output) is quantified as an output factor. With the help of further evaluation surrogates in form of hedonic and utilitarian qualities based on the levels of achieved customer satisfaction, the service quality can be assessed (Wirtz and Lee 2003). The benchmark for contractual compliance is utilitarian customer satisfaction. The customer's contractual complaints indicate deviations from the service agreements, which force legally amendments of the delivered services. Utilitarian satisfaction is therefore included in the performance assessment as an objective quality criterion by quantifying the customer contractual complaints. The subjective performance assessment is specified by hedonic customer satisfaction, which is assessed by non-contractual claims that can be compared to subjective perceptions regardless of contractual agreements. The response to non-contractual claims depends on goodwill of the service provider without any legal obligations. Handling contractual complaints and non-contractual claims causes the service provider extra effort, which is included as secondary input caused by the amendment. Apart from the qualitative output, productivity measurements should also include a quantitative output factor that focuses on the amount of delivered service.

At the third level of the model in Fig. 1 suitable input and output factors are operationalised in terms of value):

- Input factors can be determined by the costs that are incurred by providing the service.
- Outputs measure the service provision with respect to quality and quantity. The quantitative output can be calculated directly, while the qualitative output enters the productivity measurement indirectly by the increase of input factors. Thus, only the quantitative output will be quantified according to the services provided in compliance with the contract and is directly included in the productivity measurement.

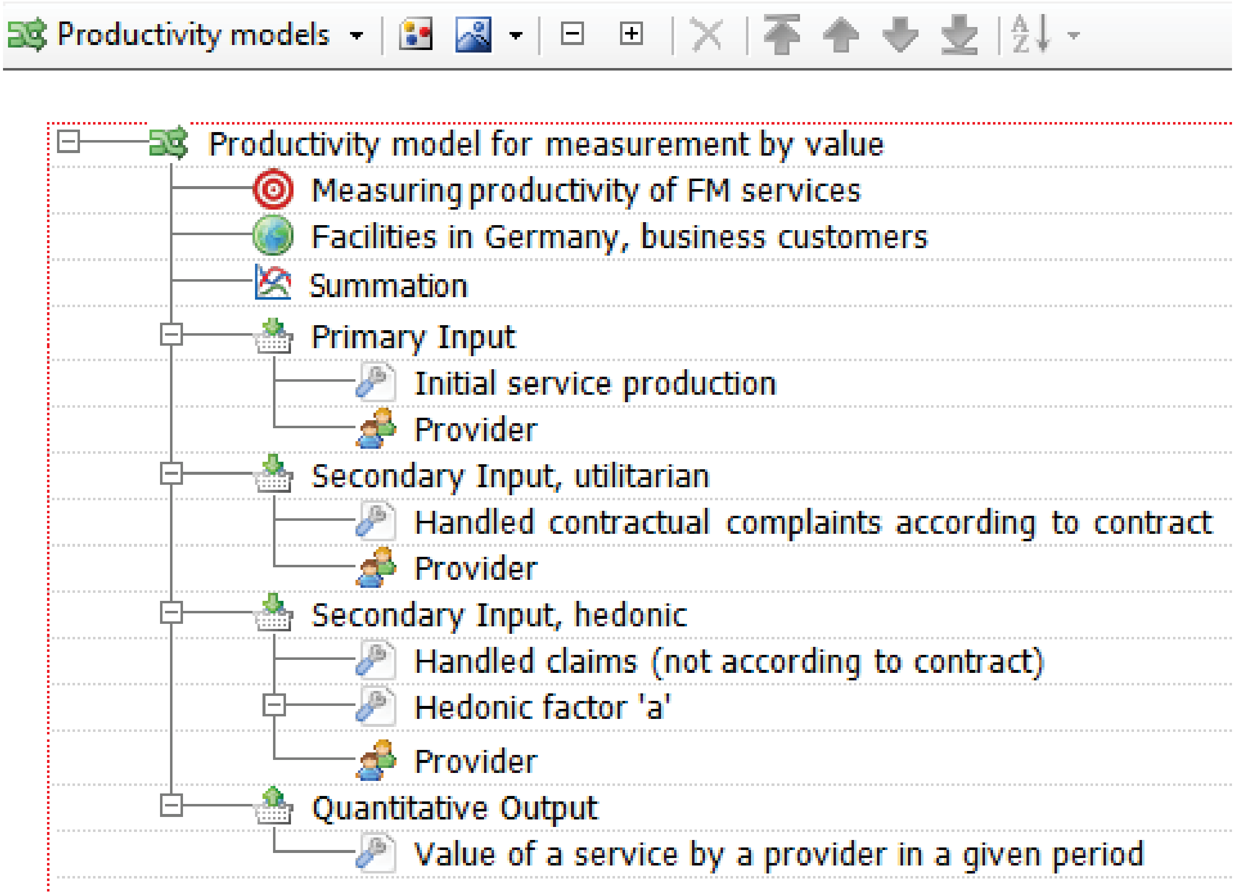
The operationalisations for both input and output factors are depicted in Fig.3. The computation of the service productivity arises from the projected input for the service provision (primary input, PI), the additional input (secondary input, utilitarian, SI_u) exacted by quality deficits and complimentary services (secondary input, hedonic, SI_b), as well as by quantitative output. With hedonic inputs, a provider considers additional customer complaints that are fixed despite not being contractually agreed. This decision is controlled by the factor 'a' to introduce hedonic quality.

$$\text{Service Productivity} = \frac{quantitativeOutput}{(PI+SI_u+(a \cdot SI_b))}$$

Thus, the calculation methods for the measurement in terms of value are basically arithmetic operations to calculate the productivity ratio above.

4.3 Measuring Productivity in Terms of Quantity

Besides measuring of productivity in FM in terms of value, it is also possible to operationalise the



Productivity model for measurement by value
- Measuring productivity of FM services
- Facilities in Germany, business customers
- Summation
- Primary Input
  - Initial service production
  - Provider
- Secondary Input, utilitarian
  - Handled contractual complaints according to contract
  - Provider
- Secondary Input, hedonic
  - Handled claims (not according to contract)
  - Hedonic factor 'a'
  - Provider
- Quantitative Output
  - Value of a service by a provider in a given period

Figure 3: Measurement of service productivity in terms of value

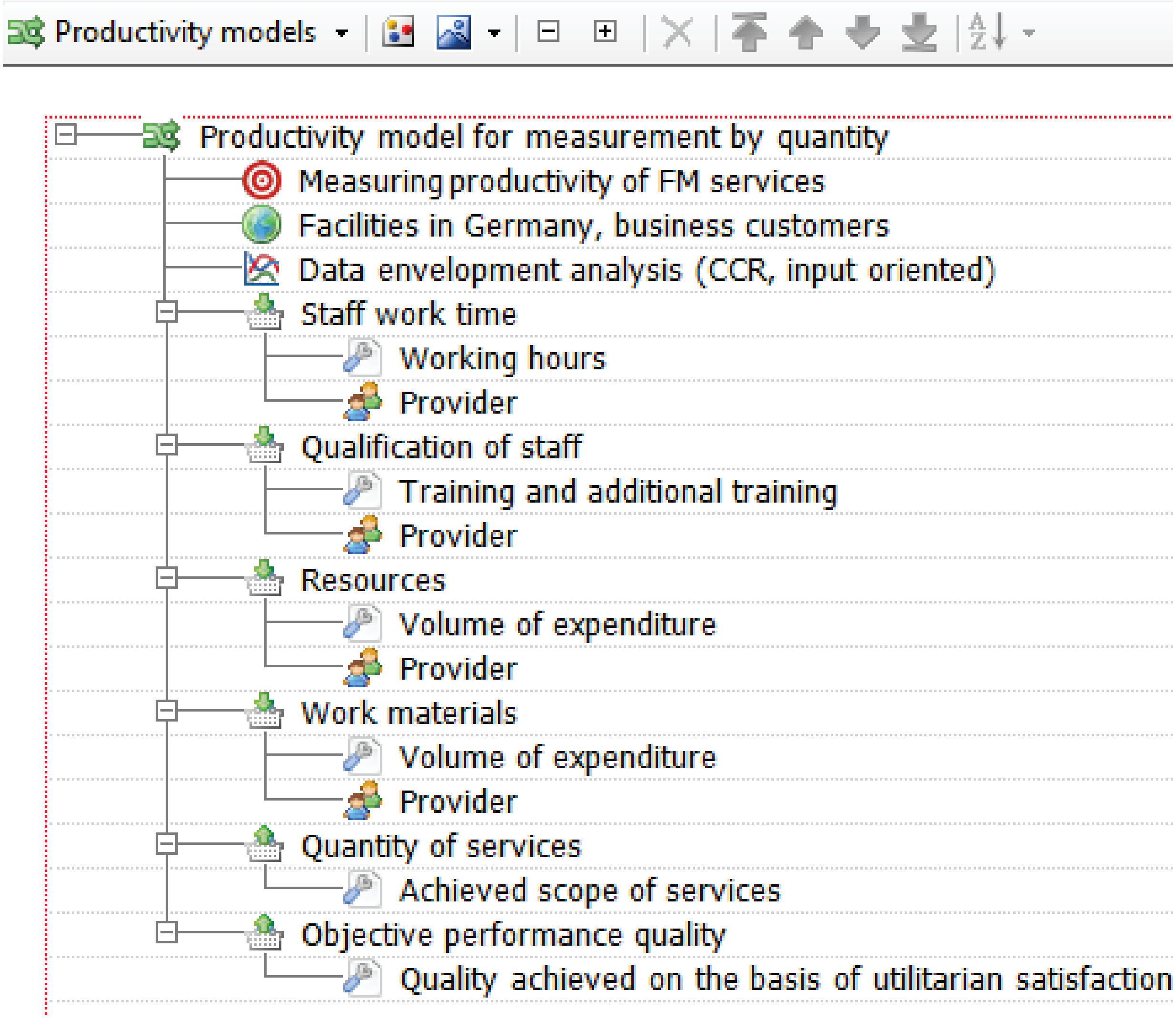
productivity factors with regard to its quantity. To do so, the *Application context* in measuring in terms of quantity refers to the assessment of productivity of facility services during building operations from the viewpoint of the service provider.

On the second level of the productivity model, the relevant productivity factors are differentiated into input and output factors (Fig. 4). For facility services, the input consists of the dimensions staff, resources and work materials, the output of service quantity and service quality.

At the third level of the model suitable input and output factors are operationalised within the scope of productivity expressed in terms of quantity. This means, that all the concepts to operationalise the productivity factors are determined by the volume that is incurred in providing the service. For instance, staff working time and training time is measured in hours, some other operationalisations in terms of volume. The same holds for the output figures. However, the measurement of performance – with respect to quality – with a Likert-scale is ordinal. Consequently, it is not possible to employ a calculation method as basic arithmetic operations. Therefore, we employ DEA to circumvent the lack of prices (or weights in the terms of DEA) for the operationalisations (Charnes et al. 1978; Emrouznejad and De Witte 2010).

5 Conclusion and Outlook

The modelling language presented in this work provides an IT artefact that is capable of supporting the construction of productivity models.



- Productivity model for measurement by quantity
  - Measuring productivity of FM services
  - Facilities in Germany, business customers
  - Data envelopment analysis (CCR, input oriented)
  - Staff work time
    - Working hours
    - Provider
  - Qualification of staff
    - Training and additional training
    - Provider
  - Resources
    - Volume of expenditure
    - Provider
  - Work materials
    - Volume of expenditure
    - Provider
  - Quantity of services
    - Achieved scope of services
  - Objective performance quality
    - Quality achieved on the basis of utilitarian satisfaction

Figure 4: Measurement of service productivity in terms of quantity

After demonstrating the applicability in the field of FM in this paper, the next steps in the evaluation process will be to carry out laboratory experiments (Becker et al. 2012a) as well as case studies and quantitative multi-method analyses in enterprises. Within the scope of this evaluation programme, it is planned to conduct a study in the field of facility management. In this paper, the conceptual foundations have been laid for this kind of domain-specific research.

Besides the evaluation of our concept, there is ample scope for further development. The language can be extended with constructs that support dedicated calculation methods. These may include advanced variants of DEA (Becker et al. 2011b) as well as substantially different approaches. Furthermore, the extension of functionality to increase the effectiveness and efficiency of the modelling should be considered (Becker et al. 2011a). Candidates for this kind of extension are, in particular, the inclusion of a discourse component to enable collaborative modelling (Casu et al. 2005) or an automated suggestion system for suitable productivity models, which may, for instance, be put into effect by including case based reasoning.

With regard to the productivity models for FM presented above, further empirical research is planned to elicit the circumstances under which companies opt for certain model variants. Investigating the factors that influence the decision between a measurement in terms of value or quantity seems to be a topic worth conducting. Provided all relevant productivity factors can be quantified, these measurements appear to be more valid and more sustainable. The great advantages of an assessment in terms of value, on the other hand, are its fairly quick applicability and its good performance on sparse data.

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