Measuring service productivity with Data Envelopment Analysis (DEA)

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The “ServDEA” projects aims for an approach based on Data Envelopment Analysis (DEA) to measure service efficiency that masters the specific challenges of a service setting, something that extant literature is still lacking. The purpose of this paper is to provide an overview of basics on service productivity and efficiency fundamentals, integrate extant concepts of productivity, introduce DEA with a focus on DEA variants that are particularly relevant for application to services, and conclude with the work in progress regarding a case study of an industrial service provider.

1. Relevance

Over the last decade many “service providing producers” on industrial markets became “producing service providers”, a development that several studies acknowledge (Freiling, 2004, Schuh; Friedli; Gebauer, 2004). A study by the German Engineering Federation (2001) shows that the profitability of industrial services (up to 20%) is much higher than that of new product businesses (+/- 1%); however, the increasing number of industrial manufacturers and independent service providers entering the market promotes an increasing pricing pressure, a development which may lead to decreasing profitability for services (Lange, 2009). A promising chance to compensate this downturn in profitability is to improve the relationship of produced outputs (revenue perspective) to used resources (cost perspective) in the service process. This relationship, called productivity, and its extended concept of efficiency, need to be measured (for a detailed differentiation of both concepts see section 2.1).

Lasshoff (2006, 1) states: “productivity is one of the most important performance parameters of a company”. This general importance of productivity and efficiency becomes even clearer if we consider the critical situation of industrial service providers mentioned above.

Also managerial practice supports the necessity to improve the understanding (and measurement) of service efficiency. Nachum (1999, 922) states, “The common accepted wisdom among economists is that productivity of services lags behind productivity of manufacturing”. Moreover, in a survey from 2006 with European service providers, 37.5 % of the respondents indicated dissatisfaction with their existing performance measurement systems which contain efficiency evaluations (Lange, 2009).

It is thus surprising that, although the “classic” concept of productivity and efficiency has been discussed extensively with regard to manufacturing goods, little effort has been made to adapt it to services (Lasshoff, 2006). Specifically, empirical studies in
the industrial service sector are mostly lacking. Out of a set of 160 studies dealing with efficiency, only five articles examine efficiency in an industrial service setting (for details see section 4.1). This makes industrial services obvious cases of application.

The “ServDEA” project aims at addressing this research gap. We develop a comprehensive understanding of service productivity and service efficiency. We also propose Data Envelopment Analysis (DEA) to measure service efficiency consistent with our conceptual reflections.

This article demonstrates the work in progress. We provide an overview of basics on service productivity and efficiency fundamentals, then integrate extant concepts of productivity, introduce DEA with a focus on DEA variants that are particularly relevant for application to services, and conclude with a case study of an industrial service provider.

2. Theoretical foundations of service productivity

2.1. Definitions of productivity and efficiency

Both constructs, efficiency and productivity, are treated ambiguously in research and daily practice (Forsund et al., 1974, Ojasalo, 1999). Although these terms are not precisely identical, they are often used synonymously (Coelli et al., 2005, Sherman et al., 2006). There is also disagreement about how to differentiate the one from the other (for divergent definitions see Lasshoff, 2006, Ojasalo, 1999, Ray, 2004).

Sink (1985, 3) states, “productivity is simply the relationship between the outputs generated from a system and the inputs provided to create those outputs”. The ratio of outputs and inputs is descriptive in nature and does not allow an evaluation of a system’s efficiency individually, because it lacks an appropriate comparison level (Ray, 2004). Specifically, it disregards a pre-determined target or best-practice as a potential evaluation standard for comparison. Such a comparison would extend the concept of productivity concept to a normative measure of efficiency (Ray, 2004).

To conclude, productivity can be considered the basis for the (relative) efficiency construct (Scheel, 2000, for a further elaboration, e.g. regarding scale economies, see Coelli et al., 2005). We will subsequently use the term “productivity” for the input-output system of one particular decision making unit; instead, we will use “efficiency” in the presence of benchmark units.

2.2. Constitutive characteristics of services and requirements for a concept of service productivity

The classical productivity formula (productivity = quantity of output / quantity of input) makes two problematic assumptions. First, both enumerator and denominator must be measured in quantity units of the same kind and dimension in each case. Otherwise it is impossible to calculate neither overall output nor overall input. To bypass this problem practitioners suggest calculating partial productivities which disregard potential relationships with residual factors, or they try to assign prices to inputs and
outputs (Barth; Hartmann; Schröder, 2007). This, however, causes even more assessment problems and also ignores exogenous influences (Corsten, 1994). Second the original manufacturing perspective assumes output quality to be constant due to a stable production process (Ojasalo, 1999). This concept thus neglects any dimension of quality or customer satisfaction.

Additional challenges in measuring service efficiency relate to the constitutive characteristics of services (Ojasalo, 1999, Meffert; Bruhn, 2009). Although literature discusses a broad selection of such characteristics, recent works subsumes them with two key characteristics: immateriality and integrativity (Bruhn, 2006, Lasshoff, 2006, Lange, 2009).

**Immateriality.** While manufactured goods are tangible and can therefore be counted to measure output quantity, services are provided in form of activities, interactions, processes, and solutions (Ojasalo, 1999). Immateriality makes services intangible and hardly observable, which hampers the quantification of service outputs (Corsten, 1994, Ojasalo, 1999). Immateriality also causes a lack in perceptibility as well as uncertainty of the customer towards service quality (Meyer, 1996). As a consequence of the absence of a presentable final good, customer regularly use surrogates (e.g. competence of staff, media appearance of the service provider) to evaluate services (Lasshoff, 2006). These surrogates refer frequently to the service potential and the service processes rather than focusing solely on the final service result.

The immateriality of services also is closely related to its perishability as intangible services are not storable for later consumption (Bienzeisler; Löffler, 2006). Consequently, more output does not necessarily imply higher productivity; instead, it is limited to the actual demand. Estimating the demand appropriately avoids two potential sorts of costs: idle capacity costs in the case of excess supply or unrealized sales in the opposite direction. Thus, an appropriate concept of service productivity must consider these capacity restrictions (Lasshoff, 2006).

**Integrativity.** This characteristic assumes a customer’s participation in producing a service. On the one hand, the customer triggers the service process in his or her role as a buyer. On the other hand, the customer is integrated into the production of services and thus serves as a co-creator (Lasshoff, 2006). These observations have consequences for the productivity conceptualization: First, the service order by a customer separates the autonomous service potential from the customer-influenced service process (Kleinaltenkamp, 2001). Second, external factors like a customer’s resources or activities have to be considered as additional inputs (Ojasalo, 1999). The service provider, however, cannot entirely control the customer’s contribution, and it also cannot determine whether the customer’s input improves or deteriorates service productivity (Mills; Morris, 1986, Lovelock, 2001, Bartsch; Demmelmair; Meyer, 2011). Third, integrativity and the subsequent closeness of the customer stress the relevance of quality for a measure of service productivity (Lasshoff, 2006). At the same time, quality depends on the customer’s participation and is therefore not under full control of the service provider anymore (Sasser, 1976).

As mentioned above both constitutive characteristics – immateriality and integrativity – implicate various requirements for measuring service productivity and thus necessitate a more complex productivity concept.
2.3. Existing service productivity concepts and integration

The conceptual reflections subsumed above have created a variety of concepts of service productivity (Examples can be found in Levitt, 1972, Lovelock; Young, 1979, Jones, 1988, Corsten, 1994, Vourinen; Järvinen; Lehtinen, 1998, Murphy, 1999, Chase; Haynes, 2000, Parasuraman, 2002, Johnston; Jones, 2003 and Grönroos; Ojasalo, 2004).

Two such concepts though have attracted particular attention (Baumgärtner; Bienzeisler, 2006, Bartsch; Demmelmaier; Meyer, 2011), those developed by Corsten (1994) and Grönroos and Ojasalo (2004). Corsten (1994) elaborates on the separating effect of the co-creating customer and divides the service production into a pre-combination and an end-combination phase. This distinction yields two productivity components, one for each phase. Thereby, service potential simultaneously serves as an output of the first and as an input of the second phase. The customer’s first-time intervention into the process constitutes the beginning of the second phase. All customer resources and efforts can be integrated into the concept by treating them as (external) input factors. Additionally Corsten extends the pre-combination productivity with a rate of utilization to address the need to consider potential capacity restrictions.

The productivity concept of Grönroos and Ojasalo (2004) can be considered the most comprehensive model in the service literature (Bartsch; Demmelmaier; Meyer, 2011). They also distinguish between different levels of customer participation (independent provider production, joined production, independent customer production) but do not derive different productivity components from this differentiation. They integrate the external factor as a customer’s inputs which together with the provider’s inputs determines the ‘internal efficiency’ (Grönroos and Ojasalo have a divergent definition of efficiency). Grönroos and Ojasalo also acknowledge potential capacity restrictions and propose a separate ‘capacity efficiency’ in their concept of service productivity. In contrast, Grönross and Ojasalo extend Corsten’s concept by considering output quality as an integral part of the concept. The combination of output quantity and output quality forms the ‘external efficiency’. All three efficiencies (internal, external, and capacity) determine the overall service productivity.

We use both concepts discussed before and merge them into a shared concept of service productivity (see Figure 1).

Fig. 1: An integrated concept of service productivity
(Sources: Corsten, 1994, 61 and Grönroos; Ojasalo, 2004, 418)
We adopt Corsten’s idea to separate the preparation phase (service potential) from the service production phase by the customer’s initial intervention into the production process. The first phase resembles the classical productivity concept used in the manufacturing sector since there is no customer participation.

But when the customer submits a service request, the service potential merges into the service production phase in form of an input. Further variable provider inputs complete the internal perspective on the input side. In contrast to the service potential these inputs cannot be prepared in advance, but rather occur ad-hoc during the service process. They are variable in nature since they do not show up without actual service demand. Consistent with Corsten (1994) as well as Grönroos and Ojasalo (2004), we consider customer inputs in the second phase. We emphasize that the particular case of application will determine whether these inputs are perceived as a burden by the customer and hence should be minimized or not.

We extend existing concepts in regard of environmental influences on productivity, which have been neglected so far. Even though these environmental factors do not generate productivity values in the classical understanding of input and output factors, they should be taken into account when services are compared to each other in terms of efficiency. Environmental circumstances may improve or deteriorate productivity even though service providers cannot control them (Golany; Roll, 1989). By including them into the efficiency calculation we can avoid biased efficiency assessments (Dyson et al., 2001). Such a corrected efficiency measure is obviously interesting for practical applications and it is more likely to be accepted as a steering tool than some other uncorrected measure.

Regarding outputs, we follow Grönroos and Ojasalo (2004) and combine output quantity and perceived output quality. The latter refers to evaluations from a customer perspective. To appropriately address the capacity issue, we allow for demand restrictions; these may relate to past or expected output quantities.

To sum up the discussion so far, our concept of service productivity integrates two prominent and widely accepted approaches. We observe a research gap specifically with respect to the operationalization of productivity rather than with its theoretical underpinnings (Bartsch; Demmelmair; Meyer, 2011). Consequently, we will describe the process of operationalization, using a case study design (section 4), after a short introduction to Data Envelopment Analysis (DEA) that constitutes the computational basis of our approach (section 3).

3. Data Envelopment Analysis (DEA) as a mathematical approach to measure service productivity

3.1 General description of DEA

Data Envelopment Analysis (in the following: DEA) is a mathematical procedure to measure efficiency of so-called ‘decision making units’ (DMUs). Since its introduction into the Operations Management literature by Charnes, Cooper, and Rhodes (1978), DEA has been widely used in a variety of applications, and a large number of methodical variants have been developed to accommodate application-specific require-
ments (for a bibliography on published articles on DEA, see Tavares, 2002, Seiford, 2006, Cook; Seiford, 2009, for an introduction to DEA and its most important variants, see the textbook by Cooper; Seiford; Tone, 2006).

A DEA compares input-output relations of decision making units (such as companies or other organizational entities). A basic assumption (the “homogeneity assumption”, see Dyson et al., 2001, 247-248) proposes that any DMU uses the same kind of inputs to produce the same kind of outputs. Only the respective quantities vary across DMUs, of course, and build the basis for the comparative efficiency assessment: The observed input-output relations, each referring to a specific DMU’s production, combined with a set of “rules” (axioms), are used to construct a set of “feasible” input-output relations. This so-called “feasibility set” does not only contain all observed input-output relations (DMUs), but also other (hypothetical) benchmarks. The feasibility set has an outer boundary, a subset that contains Pareto-optimal input-output relations, which explains that this subset is also referred to as “efficient frontier”. By measuring the distance from a specific input-output relation (DMU) to this efficient frontier, an efficiency score is derived for that DMU. This efficiency score is obviously one-dimensional but nevertheless considers all inputs and all outputs simultaneously.

The computational basis in any DEA is a linear program (LP). The efficiency score is the optimal value of the objective function. For each DMU, a specific LP has to be solved; however, the input-output relations of all other DMUs are needed to formulate the conditions of the LP. In less technical terms, DEA answers the question, “Given this DMU’s input-output relation, what is its efficiency, compared to all other DMUs?” Thus, DEA is in line with the notions of productivity and efficiency, as outlined in section 2.

The key idea behind any DEA to circumvent the problem of merging several inputs (or outputs) into a measure for overall input (or overall output) is the following: It uses weighting factors (sometimes interpreted as “shadow prices”) for all inputs (and all outputs) that breakdown the possibly different scales of the inputs (and outputs, respectively) onto the same scale. As these weighting factors are generally unknown, they are simply treated as variables in the LPs, and are thus related to the solution rather to the input of the efficiency assessment. The general structure of an LP, an objective function and conditions under which the value of this function is computed, makes DEA an approach that can be very easily adapted to specific requirements in applications. For example, some requirements can simply be implemented by including appropriate conditions. We will now discuss some DEA variants that in our view can adequately consider the key constitutive characteristics of services – immateriality and integrativity – and describe how these variants respond to the (measurement) challenges that emerge from these characteristics.

3.2 Some DEA variants for application to services

3.2.1 DEA variants to consider immateriality of services

In section 2, we discussed two important consequences of the fact that services are immaterial. First, to evaluate service output, it is necessary to consider quality perceptions of the customer (as a consequence of a potential lack in objective measures for service results). Second, service productivity cannot be assessed without consid-
Literature has introduced DEA variants that can accommodate the related requirements. The fact that quality perceptions play a major role in evaluating the outcome of a service has two different model implications. The first one has been elaborated by Kamakura and colleagues (2002) and later been used by Mukherjee and colleagues (2003). These authors basically distinguish between what in the latter article is called a “quality efficiency” model and a “profitability efficiency” model (Mukherjee; Nath; Pal, 2003). Service quality as perceived by the customer acts as a “link” between service inputs used by the service provider and some financial performance measure that relate to service sales. Service quality thus has a mediating role and makes it necessary to run a two-stage DEA. Service quality works as an output in the “quality efficiency” model and as an input in the subsequent “profitability efficiency” model. Such a “mediating” variable that enters a DEA has also been labeled as an “intermediate output”. Besides the two mentioned articles that apply two-stage DEA models in a service context, models that implement such intermediate outputs have been described extensively by Färe and Grosskopf (1996).

The second model requirement that emerges from the necessity to consider quality perceptions relates to the measurement of quality perceptions themselves. In contrast to more objective performance indicators, service quality is affected by subjective evaluations that may differ from customer to customer (sometimes, not only customers’ perceptions are relevant, but also those of service employees; see Soteriou; Zenios, 1999). It is obvious that such measures are affected by measurement errors. For example, they depend on the choice of customers or service employees (potential lack of representativity) or the moment of measurement. Moreover, quality perceptions are likely to be heterogeneous across consumers. As a consequence, it is rather impossible to measure service quality unambiguously. Thus, what is needed for a specific service to quantify its quality is a distribution of individual customer perceptions around some mean value. Altogether, so-called “Imprecise DEA” (for an overview, see Zhu, 2003) is able to reflect both challenges – measurement errors and distributions (instead of single values) of variables (in our case: service quality as an output variable).

To conclude, we turn to the challenge that for services, it is not appropriate to unconditionally claim more output to be better than less. Instead, it is necessary to acknowledge that output maximization is meaningful only unless it does not exceed actual demand. This additional requirement is related to the fact that services are impossible to store. Concerning the implementation of this requirement into a DEA model, the conditions stated in such a model simply have to consider these “upper boundaries” for the (restricted) service output. As demand for a specific service does not necessarily refer to a single DMU (i.e., service provider) but can also relate to the amount covered by all service providers jointly, the general term for such kind of restrictions used in DEA literature is a DEA model with “undesirable outputs” (for a recent development, see Gomes; Lins, 2008).

### 3.2.2 DEA variants to consider integrativity of services

The second key characteristic of services, integrativity, makes additional methodical adaptations of DEA necessary, beyond those that we acknowledged in the previous subsection. Customer co-creation means that not only the service provider, but also
the customer has an influence on the productivity of the service. Consequently, an appropriate DEA model should include variables that describe the customers’ activities related to the service. However, two characteristics of customer co-creation need attention before they can be translated into appropriate model formulations.

First, customer co-creation is likely to be uncontrollable by the service provider (or at least much less controllable than the provider’s own efforts to offer a service). Hence, although customer co-creation is likely to influence the productivity of a service, the provider cannot be deemed responsible for such an influence. In terms of an appropriate DEA model, this observation suggests that it is necessary to distinguish between variables (particularly inputs) that are under the control of the DMU (i.e., the service provider) and those that are beyond the provider’s control. In the DEA literature, various models have been proposed to consider such “non-discretionary” variables (see Cooper; Seiford; Tone, 2006). While non-discretionary variables do appear in the conditions of the related DEA programs, they are not a component of the objective function (which refers to the efficiency score of a DMU).

One problem specific to these models is that some variables that conceptually should influence the productivity do not appear to exert such an influence in the empirical analysis. In short, in the presence of non-discretionary variables, some authors recommend to test the actual influence of these variables on the efficiency assessment. The state-of-the-art approach in this context is included in a publication by Simar and Wilson (2007). The basic idea is to first run a DEA model with discretionary variables only. In a second step, a regression equation is fitted, with the DEA efficiency scores being modeled as a function of the non-discretionary variables. The final DEA model should then only consider those non-discretionary variables that significantly influence the efficiency scores from step 1. However, we should acknowledge that the methodological state-of-the-art as presented in the mentioned article has not yet been implemented in some standard DEA software. Thus, applications of such approaches in a service environment are still lacking support from automated computation.

Besides the distinction between non-discretionary and discretionary variables, where the first category encompasses customer co-creation activities, it seems necessary to specify the direction of influence these customer activities have on service productivity. Specifically, as customer co-creation can improve but also deteriorate service productivity, a test is needed to decide whether co-creation rather should be treated as an input (which is then to be minimized) or rather as an output (where maximization positively influences overall productivity). Conceptually, however, it is clear that customer co-creation is an input; specifically, as outlined above, it is a non-discretionary input. Consequently, the problem reduces itself to simply running the procedure as described by Simar and Wilson (2007), as mentioned before.

To sum up the previous discussion, we first observed that DEA is a method that “elegantly” resolves the problem of appropriately aggregating single inputs or outputs into overall input or output.

Second, immateriality and integrativity as key characteristics of services suggest the following DEA variants to play a significant role in measuring service productivity:

- Two-stage models that treat service quality as an intermediate output;
• Imprecise DEA that can encompass issues related to the measurement of service quality (as perceived by customers);
• Models that accommodate undesirable outputs;
• Models that accommodate non-discretionary variables (customer co-creation as input).

4. Operationalization approach

4.1. Literature analysis

Our theoretical considerations so far suggest that each application necessitates some adaptations. Two questions summarize these adaptations: How to identify factors (inputs and outputs) on a theoretically sound basis? How to measure these factors, given potential restrictions in data availability?

In an attempt to answer the first question, some authors argue to start with the identification of all factors that may impact the productivity of the respective DMU (Golany; Roll, 1989, Scheel, 2000). The advantage of this procedure is to likely receive a complete set of potential in- and outputs. Given this set of factors, a second step should then choose those factors that are likely to be relevant for the efficiency measurement (we will later describe some methods that support this step).

To find out how extant studies using DEA make their choices on inputs and outputs, we conducted a literature analysis. The aim of this analysis was to cover any DEA application to service settings. Therefore, we used “DEA” and “service” as keywords in our search of EBSCO’s Business Source Premier database. Two authors categorized the 160 most relevant articles (according to the EBSCO Relevance Score) separately according to the type of the industry or industries under evaluation. They also looked for any description of how inputs and outputs were chosen.

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Table 1: Frequency distribution of examined industries in DEA-literature

While DEA has been frequently applied to financial, health, and public services, industrial services have attracted little attention. Particularly, applications to maintenance and repair services are lacking. In consideration of the initially envisioned relevance of practical productivity measures for industrial services we thus identify a need for research. Especially since maintenance and repair services represent a cru-
cial element of the service portfolio of engineering companies, the following research will focus on these issues.

116 (out of 160) journal articles do not describe any procedure to identify inputs and outputs. The remaining 44 articles provide at least some explanations. However, they often follow divergent approaches for factor selection. For example, the production approach “treats the financial services companies as producers” (Lin; Huang, 2009, see also Brown, 2006), while the profit-oriented approach “defines revenue components as outputs and cost components as inputs” (Gaganis; Pasiouras, 2009); the intermediation approach in turn “takes the view that DEA Inputs and Outputs should be selected according to the services that each individual subsidiary provide” (Chao et al., 2009, see also Brown, 2006).

The intermediation approach seems to fit our purpose best since it concentrates on services. But most approaches focus on the finance industry and have a common weakness: They provide general guidance rather than an exact method to identify an appropriate set of factors. Consequently, most DEA applications “simply state the input-output variables used in the assessment rather than detail the process of their identification” (Casu; Shaw; Thanassoulis, 2005).

None of the articles we analyzed provides a method to choose factors on a theoretically sound basis. Instead, we agree with Brown, Brown, and O’Connor’s (1999, 11) conclusion: “the literature encompasses a wide range of specifications which may have as much to do with data availability as with matters of principle”.

Apart from the problem of factor generation there are some articles that discuss how to reduce an initial comprehensive set of factors. The rule “as many as necessary, as few as possible” provides rough guidance for such a reduction. A focus on key factors is advantageous since it facilitates the interpretation of results while maintaining a certain level of data quality (Golany; Roll, 1989, Scheel, 2000).

The reduction of the initial set of factors also relates to the second problem (operationalization and data availability). The practitioner is likely to consider the effort necessary to collect suitable data. In other words, the additional information of a specific factor should justify the effort to collect (additional) data.

Statistically oriented procedures to reduce the initial set of factors can base on principal component analysis, regression analysis, a non-parametric correlation analysis or even combinations of that (e.g. Medina-Borja et al., 2007). Other authors like Scheel (2000) argue in favor of a contentual (as opposed to statistical) rationale behind the reduction. He even pleads for an integration of the involved parties of the respective DMU in a contentual selection process. He argues that such an integration would later increase the acceptance of the results, and researchers would receive a “first hand” impression of the factors perceived as relevant. Again other authors combine statistical with contentual considerations. For example, Golany and Roll (1989) offer a three-stages approach (judgmental screening, interviewing business segment experts for the most relevant factors; non-DEA quantitative analysis, issues of operationalization and statistical procedures; DEA based analysis, trial runs of DEA models).

However, since our literature review did not provide a suitable method to generate a set of inputs and outputs, we developed an own procedure, which we describe subsequently. Hereby, we follow the four key criteria as proposed by Dyson et al. (2001):
• The factor set should cover all resources used;
• The factor set should capture all activity levels and performance measures;
• All factors should be common to every DMU;
• All measures have been corrected for potential environmental influences.

In line with the requirements suggested by Dyson et al. (2001), we use service blueprinting as a method to generate a starting point.

4.2. Blueprinting as a structural approach to derive input and output factors

Service blueprinting is a process visualization method introduced by Shostack (Shostack, 1982, 1984). It has been used extensively and extended also (Kingman-Brundage, 1989, 1991, 1993, 1996, Kingman-Brundage et al., 1995, Kleinaltenkamp, 1999, Fließ; Kleinaltenkamp, 2004). The key idea is to ‘visually display[s] the service by simultaneously depicting the process of service delivery, the points of customer contact, the roles of customers and employees, and the visible elements of the service.’ (Zeithaml; Bittnner, 2000). An essential benefit is its ability to uncover interaction between service provider and service customer (Kleinaltenkamp, 1999). Although this approach requires a high level of detail, it discloses a comprehensive list of factors that may be relevant for assessing service efficiency at the same time.

A blueprint is usually characterized by two dimensions: (1.) chronology of actions and (2.) areas of actions (Fließ; Kleinaltenkamp, 2004). The chronology of actions is plotted on the horizontal and shows every single step in producing and consuming that service and therefore gives an overview of the needed resources. The areas of actions are separated into six different levels, separated from each other by five lines, on the vertical axis and capture all activity levels (Kingman-Brundage, 1996, Fließ; Kleinaltenkamp, 2004):

• The line of interaction defines the instantaneous interaction between customer and service provider. All activities located above that line are performed by the service customer.

• The line of visibility separates the actions visible to the service customer from those that are visible to the service provider only. Usually, actions above this line are carried out by front office employees.

• The line of internal interaction distinguishes front office and back office activities. All activities that are necessary to enhance front office employees in delivering a service are carried out beneath the line of interaction.

• The line of order penetration distinguishes customer-induced activities from customer-independent activities. The latter only rely on the service provider’s internal production factors. Above this line all activities are initiated by a customer’s service request.

• The line of implementation mainly separates managerial functions from daily service activities.
In our study, the line of interaction and the line of order penetration are particularly important. They perfectly reflect our integrated concept of productivity. While the line of interaction distinguishes the internal from the external perspective, the line of order penetration separates the service potential from the actual act of a customer-induced service production. Blueprinting therefore integrates a process-orientated view (with focus on all activity levels) and the two-stage productivity model (which suggests a set of relevant factors) (Lasshoff, 2006).

We illustrate the maintenance service blueprint with an example of a German machine tool manufacturer. The data for this illustration and the later following empirical analysis come from a German machinery engine manufacturer. This company has six regional service units within the German market, which will serve as DMUs and hence be focus of the efficiency benchmark. These service units performed approximately 280,000 service and maintenance operations in the years 2009 to 2010. All data has been provided as a database extract in Microsoft® Access:

Some adaptations to the above presented service blueprint model were necessary though. The customer’s resources have been covered as well. That will simplify the later following extraction of customer-induced inputs. Moreover, the area between the line of internal action and the line of order penetration has been split into two zones. The upper zone represents tasks that are immediately susceptible by the business unit and hence underlie the unit’s responsibility. The lower zone instead is beyond the business unit’s control. This modification was necessary to appropriately address different degrees of managerial influence. Additionally, the area below the line of order penetration designates the provider’s resources.
4.3. Input and output factor extraction

Comparing the integrated productivity concept with the detailed service blueprint the extraction of factors can now be carried out. Following the service productivity concept the service potential appears beneath the line of order penetration and is hence defined as the provider’s resources. Consequently the first three factors being extracted are:

- number of hotlines
- number of engineers
- engineer’s training level

These factors are the outcome of the service potential preparation phase. To provide this service potential, a company has to make certain investments. Therefore, the provider inputs in this phase are financial factors such as:

- costs for hotlines or the costs for engineers and trainings.

These inputs do not explicitly appear in the service blueprint. However, we can assume them to be infrastructural requirements which in turn appear below the line of implementation.

Above the line of order penetration the customer-induced activities are located; they represent the second stage in the productivity concept. In this stage the service potential as well as the provider inputs (only those that are not already included in the provider’s resources) and customer inputs are combined in the service production phase. This leads to two different output categories: output quantity and perceived output quality. Output quantity in a service setting cannot be measured by simply counting performed services due to the heterogeneous character of service activities. Therefore two requirements are related to output quantity: First, the number of performed services must be covered; second, an appropriate measure should consider the complexity of the service production. We therefore suggest two alternative output measures:

- The number of services performed within a period of time, weighted with the degree of complexity: As some machines are more complex to service than others, a classification of machines valuating their complexity should be developed. This classification can serve as an indicator for service complexity.

- The sum of conducted service hours: Each service case is determined by its time. The more complex a case is the longer it takes to maintain the machine. Time therefore can be used as an indicator for complexity. Thus the sum of service hours is a combination of the number of performed service cases and their respective complexities. That implicitly considers the requirements of service output quantity.

The perceived output quality is a multidimensional construct that can be characterized by at least three different perspectives (Bruhn, 2000): the provider’s perspective, the customer’s perspective, and the perspective of potential competitors. As we analyze six regional service units within the German market we assume the competitive environment to be equal to all units. We focus on the interaction between provider
and customer. Using the service blueprint as described above, we identify several quality measures:

- **When the customer contacts the hotline the availability of the service employee as perceived by the customer could be considered an important factor that determines productivity. The perceived availability can either be measured as rate of busy signals caused by the limit of hotlines or as an item in a customer satisfaction survey.**

- **Down time of a machine is an essential burden to the customer’s financial situation and long down times can suggest low service quality. Down time could be measured as the time lag between the initial customer’s call for repair and restarting the machine. However, a more customer-orientated approach would measure the appropriateness of down time, given the complexity of the repair case. Such a measure could be collected through a customer satisfaction survey.**

- **Furthermore, items that reflect the customer’s general satisfaction concerning the hotline, the service engineers, or the service production itself could be considered.**

- **To determine not only the perceived quality but also the objective quality, the ratio of required follow-up services and all services produced could serve as an indicator for a service provider’s perspective of quality.**

Service productivity can also be influenced by factors that are out of the business unit’s control. If these factors are not explicitly considered, a biased efficiency evaluation could occur. Therefore a distinction regarding the responsibilities and hence the managerial influence of the business units has to be implemented in our concept. The blueprint shows that the company’s central unit is responsible for the delivery of spare parts. Thus time lags or negatively perceived quality due to spare part deliveries are not the business unit’s responsibility:

- **We therefore suggest implementing non-controllable factors as environmental factors, which in our case could either be measured as the perceived speed of spare parts delivery (through a customer satisfaction survey), or as the time lag between spare parts order and delivery.**

The service production phase does not only depend on the service potential but also includes variable provider inputs and customer inputs. While in our particular case there are no variable provider inputs, customer inputs can influence the productivity intensively. Especially the quality of customer cooperation should be considered an important factor. We assume that customers who bring more revenue to the company than others also have a higher degree of experience regarding the interaction with the company and hence provide a higher quality of cooperation. We therefore propose:

- **The categorization of customers into different revenue classes should serve as an input factor to uncover the quality of customer cooperation.**
5. Outlook: Next steps

Our considerations to derive inputs and outputs have been theoretical in nature. However, given a specific practical application, it is necessary to examine whether they are meaningful (validation step). Moreover, we have to check for data availability. In order to address these concerns we propose to conduct interviews with experts in the field. These experts will first decide whether our set of factors is exhaustive (see the approach by Scheel, 2000), and potentially modify the set of factors. In a second step, data availability for these factors will be checked.

This procedure – starting with blueprinting for maintenance and repair services and ending with a data availability check – will be applied to other companies with comparable service offerings as well. The different case studies will then be compared to each other, in an attempt to make generalizable conclusions. These results will be implemented in a software tool that is based on DEA and helps industrial firms measure their service productivity.

References


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