Basic Considerations on Business Process Quality

Matthias Lohrmann, Manfred Reichert

Ulmer Informatik-Berichte

Nr. 2010-04
Juli 2010

Basic Considerations on Business Process Quality

Matthias Lohrmann[1,2] and Manfred Reichert[1]

[1] Institute of Databases and Information Systems, Ulm University, Germany
[2] KPMG AG Wirtschaftsprüfungsgesellschaft, Berlin, Germany
mlohrmann@kpmg.com, manfred.reichert@uni-ulm.de

Abstract. Quality management practices in manufacturing and logistics have led to proven results for organisations with respect to competitiveness and profitability. At the same time, business process management not only addresses a comprehensive functional scope including the ever more important administrative functions and business services, but also contributes to realising potentials (e.g. in the field of process automation) through extensive use of information technology. Integrating quality management with business process management concepts is thus very promising from a business perspective. The evolution of a clear understanding of business process quality constitutes a fundamental prerequisite for progress in this field as only a concise definition will point out the issues that need to be addressed in more detailed research. This paper aims at discussing basic considerations in this respect. We look into requirements to be posed towards a definition of business process quality, discuss various basic quality views and their fit with business process management, provide a fundamental if not yet practically applicable business process quality definition, and examine related aspects of business processes as well as related work. While this approach will not lead to a final applicable definition of business process quality, its contribution will lie in entering into a more systematic discussion to encompass the wide array of existing results that can be correlated with business process quality and giving directions for future research.

1 Introduction

Since the 1980s, the impact of quality management (QM) practices, like design for quality or statistical process control, on product quality and also on business performance has been established through empirical studies [1,2,3,4]. Although product quality and quality management practices are obviously by far not the only determinant for business performance, most studies found these factors to wield significant influence in terms of competitive advantage and, ultimately, sustained profitability. It is therefore not surprising that QM has evolved into one of the most pervasive management practices. An overview on its various forms, which are often subsumed under the term *Total Quality Management* (TQM), can be found in [5].

Traditional QM puts a strong emphasis on operations (for industrial businesses, this means manufacturing and logistics) and partially services[1] as comprised in the primary activities of an organisation according to Porter [8]. Beyond that scope, business process management (BPM) in equal measure addresses other primary and secondary activities that may be subsumed as administrative and overhead processes, i.e. the materials and labour that do not directly enter into end products. Since the relative weight of administrative and overhead processes has been growing for decades in terms of the total cost base of organisations to well beyond 50% in most industries [9,10,11], this characteristic has been a very important factor to the success of BPM as a corporate practice. Moreover, BPM provides organisations with a wide array of IT-supported methods and tools to facilitate effective and efficient adoption.

Considering the proven merits of QM with respect to competitiveness as well as profitability and the comprehensive functional scope addressed by BPM, we expect that bringing these concepts together may lead to substantial benefits for organisations by extending the field QM can be leveraged in. In addition, it is promising to investigate how appropriate QM practices can be promoted by integrating them with IT-based BPM methods. It will thus be rewarding to assess how QM and BPM concepts can be aligned.

To be utilised effectively, QM always starts with specifying a notion of quality the organisation aspires to achieve. Therefore, it is a crucial first step towards QM for business processes and the objective of this paper to develop a notion of *business process quality* which is based on QM insights, fits well with BPM concepts and methods, and can be applied in a practical business environment.

In Section 2, we frame some practical requirements for a business process quality definition to ensure practical applicability of our results. Section 3 discusses common definitions for the term business process as well as basic notions on quality. In Section 4, we derive our fundamental definition of business process quality and show that this approach leads to issues with respect to the requirements set out which we cannot easily resolve. On that basis, we enter a more detailed discussion of quality-related aspects of business processes in Section 5. This will facilitate to review existing work in relation to business process quality in Section 6, and to identify remaining gaps and directions for future research in Section 7.

2 Practical Requirements Towards Definining Business Process Quality

We judge practical applicability by matching our results with respect to defining business process quality against three fundamental requirements. The require-

[1] The quality of services provided to external customers is comparable to industrial operations as well as "internal" administrative functions and constitutes a distinct area of research. See, for instance, [6,7].

ments have emerged in our discussions with BPM practitioners from various industries and will be subject to empirical assessement in the future course of our research. We stipulate that these requirements constitute prerequisites for QM to be effective in a BPM context:

1. *Quality Measurability:* According to Deming, not everything that is important in management can be captured in visible figures [12, p. 121]. Nevertheless, a meta-analysis on empirical studies suggests that core QM practices, which are mostly based on quantitative measures like statistical process control, positively influence quality as well as operational performance [13]. This relationship has been recognised by many authors on quality management. For instance, Crosby established quality measurement as one of his 14 steps for quality improvement [14, p. 114]. Accordingly, management should strive to base statements and conclusions regarding quality on concise quantitative measures to facilitate appropriate controlling practices. We stipulate that quality measures should be available on a ratio scale where possible or at least on an interval scale. Ideally, quality measures are comparable over three dimensions: time, processes and organisations. The dimensions are based on the management practices of controlling over time, management incentivation and benchmarking between organisations. Measurability also subsumes that quality measures should not only be formally well-defined but also applicable in practice; i.e. the effort involved may not exceed the benefits to be gained (see for instance the IFRS framework, [15, paragraph 44]).
2. *Quality Accountability:* For each organisation, it is crucial to recognise that the quality of its operations and products is determined by the actions of its responsible personnel. In the end, quality is a people matter. Any notion of business process quality should thus be devised in a way that clear organisational accountability for quality can be established. Quality assessment results should be structured in a way to reflect accountable roles in an organisation, i.e. it should be possible to tell who is responsible for good or poor quality without further analysis. This will be a prerequisite to utilise results effectively for quality management and to drive actual improvements.
3. *Quality Transparency:* Statements and conclusions on quality should be transparent and retraceable, i.e., accountable managers must understand the link between status, actions and results. In a way, this requirement is an additional condition attached to the requirements of measurability and accountability: Transparency can be reached if measure definitions and procedures are not too complex or intricate. In addition, transparency is promoted if the accountability link to organisational roles is straightforward, for instance via corresponding job descriptions.

To illustrate the case for our three requirements, consider the following example for a specific business process quality definition: assume that business process quality in a service business is defined in a way that, at year end, one customer is chosen at random and asked anonymously whether he perceived quality as poor or good. This approach fulfils none of our requirements: results are not measured on a ratio or interval scale, we do not know who interacted with the customer and therefore is accountable for his or her quality perception, and it is not transparent how the customer arrived at his judgement. Therefore, this quality definition is not very useful for management purposes: For example, if the quality next year is still “poor”, we do not know whether our efforts led to any improvements or not, we do not know who of our staff we should approach to discuss this result, and we do not know what exactly annoyed our customer.

To improve on this condition, we could interview one representative sample of customers for each service team. We might ask the customers to state if they were satisfied based on a clearly defined set of criteria. This would provide us with a rate of satisfied customers per team, thus fulfilling all three requirements. We could, for instance, track the rate of satisfied customers over time and identify particularly good and bad teams. For each team lead, it would be transparent how the customers arrived at their conclusions. However, as we will see later, this practical applicability will still not be sufficient for an effective definition of business process quality as other important aspects of business processes are not considered!

3 Preliminary Considerations

In this section we shortly review common approaches to business processes and aspects of quality. This background information is needed to obtain a basic understanding on business process quality.

3.1 Common Business Process Definitions

The notion of business process first gained wide-spread recognition during the early 1990s as the concept of business process reengineering became popular with managers and consultants. Business process reengineering was advocated by authors such as Davenport and Short or Hammer and Champy as a radical way of changing and improving economically-oriented organisations [16,17,18,19]. Interestingly, the main motivation cited by the authors was American companies' quest for a competitive response to the tremendous success of Japanese corporations at the time which has also been linked to their perceived lead in quality management.

Davenport defines a business process as follows:

> “A business process is simply a structured, measured set of activities designed to produce a specified output for a particular customer or market [...] A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs.” [18, p. 5]

Concurrently, a quite similar view was developed by Hammer and Champy:

> "We define a business process as a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer." [19]

While many authors have discussed these definitions [20], their core content has basically not changed until today and has achieved wide-spread acceptance[2]. We can therefore refer to the definition advocated by a well-established trade association. The Workflow Management Coalition (WfMC) defines the term business process as follows:

> "A set of one or more linked procedures or activities which collectively realise a business objective or policy goal, normally within the context of an organisational structure defining functional roles and relationships." [22, p. 10]

Overall, the authors agree that business processes consist of set of activities which is linked to process input as included in the definitions above and to process output or the realisation of a business objective. While process input is not explicitly mentioned in the WfMC definition, each activity uses certain resources of a kind, so the requirement for process input is implicitly comprised in the notion of a set of activities.

In our further considerations, we moreover need to distinguish between a business process model as an abstract notion and business process instances as concrete enactments thereof. This distinction is supported by the WfMC definition of a process instance as "the representation of a single enactment of a process" [22, p. 16]. Business process models and business process instances are described in a model proposed by Weske based on the UML class diagram notation [23, p. 94]. Hence, in our context we will interpret the term business process as the set of all business process instances of the respective business process model, depending on the context either in total or within a given timeframe.

We will also use two additional concepts: up- and downstream business processes and artifacts. Up- and downstream business processes denote related business processes in process chains in the sense that an upstream process's output constitutes input for a downstream process. Note that aggregation and de-composition of processes into super- and sub-processes is supported as well (see Section 5.1). Artifacts denote all tangible objects or information items that are used by, created in or altered by a business process.

[2] Contrary to the definition by Hammer and Champy and in agreement with Davenport, a certain ordering of activities or control flow today is generally assumed. Notable exceptions are business process management approaches in the context of case handling where additional degrees of freedom are required to cope with complexity (see for instance [21]).

3.2 Basic Notions on Quality

Since the 1950s, quality management has become one of the central management concepts adopted by organisations globally. During that time, concepts and notions for quality have evolved from the works of pioneers such as Shewhart, Deming, Crosby, Feigenbaum, Juran and Ishikawa to standardised terminologies and methods that are propagated by trade and governmental bodies (for an overview see [24]).

In terms of practical adoption, the notion of quality most widely spread today has been developed by the International Organization for Standardization (ISO) in the ISO 9000 series of standards [25]. As a set of norms in the area of quality management for business applications, ISO 9000 has achieved broad acceptance through endorsements by governmental bodies like the European Union and the ISO 9000 certification scheme [26,27,28]. For a general notion of quality, we can therefore resort to the definition given in the ISO 9000 series of standards: quality denotes "the degree to which a set of inherent characteristics fulfils requirements".

This definition duly reflects a fundamental issue relevant for all approaches towards quality management: determining quality is always based on a comparison to an ideal, target or standard that sets requirements for the object in question. In the following sections, we refer to this as *quality standard*. By defining a quality standard considering the requirements set out in Section 2, we create a specific definition of quality and thus enable quality management. Inversely, if we want to apply quality management to a construct (e.g. a business process or an unit of business process input), we have to define an appropriate quality standard which is tantamount to developing a construct-specific quality definition.

In the course of the evolvement of quality management as a discipline, various fundamental views on quality have been argued. These fundamental views basically correspond to differing classes of quality standards. As a basis to further develop our understanding of quality with respect to aspects of business processes, we discuss these views along a widely used classification by Garvin [29,30]: quality can be discussed along "the *transcendent* approach of philosophy", "the *product-based* approach of economics", "the *user-based* approach of economics, marketing, and operations management", and "the *manufacturing-* and *value-based* approaches of operations management".

Example 1. For an initial overview, Figure 1 illustrates differing views on quality with a product quality example.

We also give an initial indication on the fit with our three requirements from Section 2 and with BPM in general. Our appraisal regarding the requirements set out focus on measurability and transparency because accountability is more a question of how the quality management object has been defined rather than how quality is interpreted.

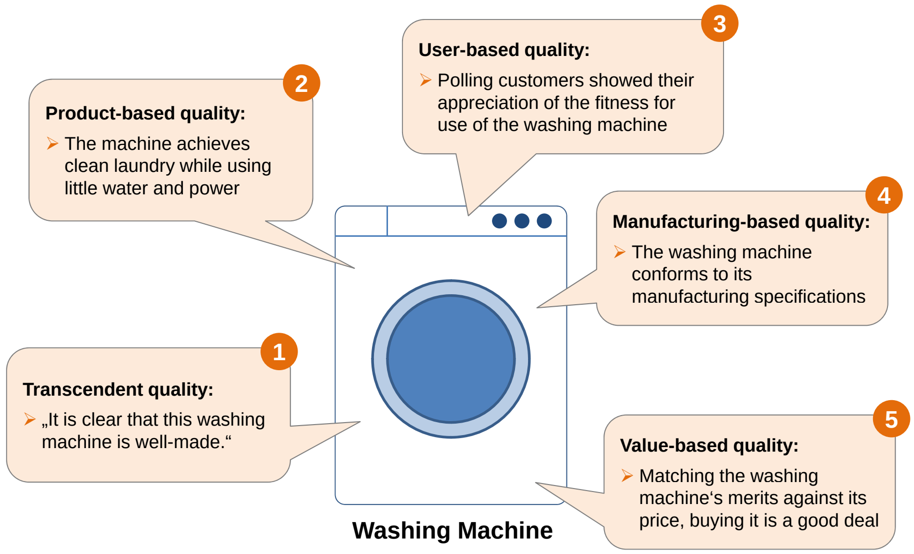

Figure 1. Quality views example

3.2.1 The Transcendent Approach

The transcendent view is the only approach that defines quality independently of the perceptions or requirements of individuals or organisations, such as customers, and therefore without an utilitarian or economic perspective. Instead, according to this approach quality refers to "innate excellence" that is in principle applicable to all concepts in a BPM context and independent of any external factors. While this view is deeply rooted in classical and modern Western philosophy [31], it is consequently not in line with the ISO 9000 definition. Moreover, BPM is aimed towards *business* process support [32]. Obviously, this implies an economically motivated context. While we duly recognizing its role in disruptive innovation [33,34], we must conclude that transcendent quality is not appropriate for BPM applications, since BPM in itself is motivated by economic or business-oriented targets. Moreover, the abstract nature of transcendent quality or quality as excellence does not lend itself to practical quality assessment or measurement [35] because results cannot be considered as objective, thus violating the measurability and transparency requirements. This is another obstacle towards its practical applicability in a management context such as BPM.

3.2.2 The Product-based Approach

The product-based view centers on measuring concretely defined quantifyable and desirable attributes in products [36]. In a BPM environment, we can substitute the term product with the output of a business process, which also includes end products. The higher the quantity of a quantifiable attribute that we find in an unit of business process output, the better its quality is judged. Hence, this approach can be directly linked to process output as a central construct in BPM, and it supports management applications by enabling measurement. As an example, consider the process of dejamming telephone landlines. A short cycle time should hopefully be a desirable process output attribute for any provider and will therefore constitute a valid quality measure in the product-based quality view.

However, the product-based approach in a BPM context addresses process output only. In a BPM context, this is not fully satisfactory as process input, process execution and therefore the economic viability of business processes are not considered at all which is clearly not sufficient in a business context. Product-based quality management always needs to be suitably complemented. An additional issue relates to the relative weight of attributes considered for quality assessment if more than one product characteristic is analysed. For instance, low weight and high stability are attributes that are both valued in bicycle frames. How we judge the relative merits of a heavy but robust frame against a light but fragile one depends on the relative weight we allot to both characteristics, which may constitute a major issue if our customers judge differently.

Thus, we can conclude that measurability according to this approach is typically given because only well-defined quantifyable attributes need to be considered. On the other hand, in many cases transparency is impeded: the relative weighing of multiple attributes can usually not be done analytically, but needs to be estimated.

3.2.3 The User-based Approach

The user-based view takes the product-based approach one step further by replacing measurable attributes of products (or process output) with the satisfaction of a user or customer.

In principle, the same conclusions apply as to the product-based view regarding measurability and applicability in a business context. The major difference is that this approach is more inclusive and leads to more effective quality assertions: not only selected, but all product or output attributes are considered, and criteria are weighed to reflect user satisfaction; i.e. there is only one scale of measurement. This allows for analytically well-founded normative statements on quality. In the product-based approach, this is only possible if just one product attribute determines quality. On the other hand, the weighing of product or output attributes to effectively reflect user preferences (e.g. across a broad customer base) constitutes an additional layer of complexity that is not easily resolved. This as well as the alternative approach of polling users directly severely impedes traceability.

3.2.4 The Manufacturing-based Approach

The manufacturing-based view focuses on conformance to specifications instead of achieving optimum measures for certain product attributes or user satisfaction. Similar to the product- and user-based approaches it is output-centered, but implicitly recognises differences between optimum user satisfaction and aspired attribute values. It can be argued that the ISO quality definition has been derived from this view on quality as it also stresses conformance to requirements.

The rationale behind this is that optimum user satisfaction or optimum attribute values might not be economically sensible from the organisation's point of view. Insofar, the approach indirectly incorporates economic considerations which corresponds well with the context of BPM. Moreover, approaches towards manufacturing-based quality mostly include engineering ("design for quality") and production control, thus managing quality not only on the basis of process output. With respect to measurability and transparency, the manufacturing-based approach features the same advantages regarding measurability as the product-based approach, but also the same issues regarding comprehensive quality measurement across multiple attributes and transparency.

Quality in the manufacturing-based approach also lacks a direct link to common quality expectations: under the manufacturing-based approach, it is easily conceivable to have high-quality process output that does in no way satisfy the expectations of customers or users, but fully conforms to specifications. From a business perspective, high-quality manufacturing is therefore not sufficient but needs to be complemented by defining high-quality specifications to conform to.

3.2.5 The Value-based Approach

The value-based view on quality incorporates the economic environment of organisations even more as it defines quality not only in terms of product attributes and user expectations, but puts these in relation to the cost or price involved. According to this view, good quality is achieved if a product or process output does not only meet expectations, but also comes at a reasonable cost [37, p. 1]. This reflects the inclusive and economic nature of BPM best as it considers resources consumption as well as output, and additionally incorporates economic considerations.

However, Garvin rightly notes that this view on quality is hard to apply in practice: it is difficult to comprehensively evaluate process input and output in economic terms, which leads to issues with our measurability and transparency requirements. This can be illustrated with the following examples:

- If a process delivers output that is not directly sold in the marketplace, its value to the organisation cannot be trivially measured. An example for this are research and development processes that do not lead to new products.

– Externally procured process input or upstream process output as input for downstream processes cannot be valued at cost without further considerations. For instance, supplier selection might not have been fully effective, or upstream processes might not be designed optimally.
– Risks associated with process input or process execution are difficult to appraise. For instance, a supplier might provide process input at a better price but with added risk of not being able to deliver in time.

3.2.6 Summary: Views on Quality and BPM Requirements

Based on Garvin's structure of quality approaches, we can summarise initial considerations with respect to quality views and our requirements from Section 2 as well as the general BPM context in Table 1.

Quality View	*Fit with BPM Context*	*Fit with Measurability and Transparency Requirements*
Transcendent approach	No fit: does not correspond to a business context	Not measurable Not transparent
Product-based approach	Limited consideration of economic aspects	Measurability given Limited transparency in case of multiple attributes
User-based approach	Limited consideration of economic aspects	Measurability given Severely limited transparency in case of multiple attributes
Manufacturing-based approach	Indirect consideration of economic aspects by definition of economically viable specifications	Measurability given Limited transparency in case of multiple attributes
Value-based approach	Consideration of economic aspects by reflecting cost / value relation	Limited measurability due to complexity Limited transparency due to complexity

Table 1. Quality views vs. BPM context and quality assessment requirements

4 Fundamental Business Process Quality

According to Section 3.2, we can turn to the requirements posed towards business processes to define a quality standard. Based on the WfMC definition, the foremost requirement for business processes is to realise a business objective. We understand the business objective as achieving a state of the organisation where pre-determind criteria are fulfilled – this will be discussed in detail in Section 5. However, this is not yet sufficient as a quality standard: intuitively, it is conceivable to have two business processes that both assuredly realise the same business objective, but still divert widely in what we perceive as quality. This is because we need to consider a second aspect as well: the term "business process" implies an economic orientation or striving to maximise profits which, in turn, means that business objectives should be realised as economically or cost-efficiently as possible. Thus, a fundamental quality standard for business processes can be defined as consuming minimum economic value to achieve a given business objective. This results in the following definition:

Definition 1. ***Fundamental Business Process Quality:*** *For a given business objective, fundamental business process quality is defined as the relation between minimum economic value consumed by an optimum business process to achieve the business objective and actual economic value consumed by the business process assessed to achieve the business objective.*

Formally, fundamental business process quality can be expressed as follows:

$$fPQuality_{bo} : \mathcal{P} \to [0,1]$$

$$fPQuality_{bo}\,(P) := \begin{cases} \frac{evc_{min,bo}}{evc_{act,bo}(P)} & if\; achieved\,(bo) \\ 0 & otherwise \end{cases}$$

$$evc_{act,bo}\,(P) \geq evc_{min,bo} > 0 \Rightarrow fPQuality_{bo}\,(P) \in [0,1]$$

where $fPQuality_{bo}$ denotes fundamental business process quality with respect to a business objective bo, P denotes a business process in the sense of a set of process instances, $\mathcal{P}$ denotes the set of all business processes, $evc_{min,bo}$ and $evc_{act,bo}\,(P)$ denote minimum and actual economic value consumption to achieve a business objective bo (see Section 5.2), and $achieved\,(bo)$ denotes whether the given business objective has been achieved (see Section 5.1.4).

In other words, optimum business process quality reflects the absence of waste (i.e., $fPQuality_{bo}$ assumes the optimum value of 1). Note that economic value consumption is always positive according to the notion that there are no activities that do not use any resources[3] (see Section 3.1). Our fundamental definition corresponds to the manufacturing-based view on quality in the sense that the business objective is treated as a specification the process has to adhere to and to the value-based view in the sense that we consider the economic value of resources consumption. Note that fundamental business process quality according to our definition always relates to a given business objective[4]. Altering the business objective but a little always results in the need to re-assess business process

[3] We also require a direct causal link between business process and business objective, so there are no business objectives that are achieved without a business process's contribution , i.e. without activities (see Section 5.1.1).

[4] According to the WfMC definition, we assume one business objective per process. However, as we will see later, business objectives can be nested, i.e. aggregated arbitrarily, so it is possible to combine aspired targets from different management domains into one business objective for one business process.

quality. This view is based on the WfMC definition of business processes which implies a business objective as preliminarily granted. Nevertheless, we recognise that irritations may be caused because, accordingly, a business process which produces superior output with equal resources would not be considered as better in quality. A short discussion on this topic is therefore included in Appendix A. If a business process model is not capable of reaching the given business objective in the first place, we can consume indefinite resources without ever achieving the business objective, so business process quality will tend to zero. Likewise, we do not consider "gradual" achievement of business objectives (see Section 5.1.4). This means that if a business process in the sense of a set of process instances does not achieve its business objective, its fundamental quality will be zero as stated in our definition.

We now can match our fundamental definition against the requirements set out in Section 2.

1. The measurability requirement leads to three main challenges for our fundamental definition. First, quality measurement presumes knowledge on the resources consumption of a hypothetical optimum process with respect to the business objective. Second, the economic value consumed by a business process is hard to measure in practical settings. To illustrate this, consider the valuation of upstream processes output. This may be done at costs of a possibly sub-optimal process or at market rates that might be difficult to obtain. Other examples are the cost for employing capital goods or the valuation of risks incurred from non-compliance to public regulations. Third, the dependency on a given concrete business objective impedes comparability over time, between varying business processes and between organisations as any change on these dimensions will lead to a change in the business objective; e.g., when considering changing output quantities required. Overall, we can subsume that our fundamental business process quality definition will not lend itself to concrete measurement in organisations.
2. The accountability requirement poses another issue because of the very inclusive nature of our fundamental definition. Consider the roles in a typical organisation that will influence the fundamental quality of a business process by setting business goals, designing processes, implementing processes, providing process input or enacting processes. As all these tasks are typically carried out by different roles, but contribute to a common quality measure, it will not be feasible to establish appropriate accountability.
3. Fulfilment of the transparency requirement is generally advanced by the simple nature of the fundamental quality definition. However, problems arise in conjunction with our considerations on measurability: the complexity issues that impede measurability also hinder transparency from an individual manager's perspective.

In summary, we can reach a fundamental definition of business process quality in a straightforward and comprehensive manner. However, when matching this definition against the requirements we set out, we must concede that its practical applicability will be severely limited. To resolve this issue and foster real-world relevance, we need to compromise on a fully comprehensive view on quality considering two aspects:

- An approach based on comprehensive economic value assessment will be too complex to be applicable in real-world settings, so we have to accept a trade-off by identifiying "proxy" measures for relevant aspects of business processes instead. These should be apt to reflect the fundamental quality standard while fulfilling measurability and transparency requirements. For instance, this might be achieved by assessing reasons for deviations from the quality optimum.
- We need to consider various stages in a business process lifecycle to reflect the involvement of different roles in an organisation and thus achieve accountability: the object of each quality measure should be within the domain of control of a role in the organisaiton.

To reflect these conclusions, our approach will be to "decompose" our fundamental quality definition into relevant aspects of business processes that can be subject to individual measures. These aspects will then be further analysed along business process lifecycle stages that can be linked to accountable organisational roles and provide a clearer notion on what can be considered as an optimum process. Based on the ISO quality notion, we will then be able to define appropriate quality standards for business process aspects within lifecycle stages as objects of quality management. This will facilitate comparison to existing approaches and identification of gaps where further research will be rewarding.

5 Quality-Related Aspects of Business Processes

As argued in Section 4, we aim to identify aspects of business processes that are relevant to quality and can be subject to quality-related measures in practice. Based on the components of our fundamental business process quality definition, we thus enter into a more detailed discussion of business objectives and the consumption of economic resources by business processes.

5.1 Business Objectives

According to the WfMC business process definition and in line with the utilitarian nature of business processes, each business process is linked to a business objective - if there are activities within an organization that are not linked to a business objective, they do not constitute a business process.

In this section, we first derive requirements we pose towards the definition of valid business objectives for the purposes of quality assessment. We then discuss existing approaches to business objectives, adapt the best suited approach to reflect our requirements, and provide a formal definition of the achievement of business objectives, which is a prerequisite for quality assessment.

5.1.1 Requirements for Valid Business Objectives

According to Definition 1, we need to establish whether or not a business objective is achieved as a prerequisite for quality measurement. A process in the sense of a set of process instances that achieves its business objective can be characterised as effective (the classic notion of "getting the right things done" [38]) . We therefore require a clear understanding on how a business objective must be made up and described to allow for its use as effectiveness criterion. In this respect, we can derive requirements for valid business objectives that enable business process quality assessment from our fundamental business process quality definition:

1. A business objective must be defined in a way that allows to clearly establish whether or not the business objective has been achieved. A business objective is to be understood from a comprehensive business model perspective and corresponds to a desirable state of a sub-domain of the organisation. This means that *the business objective corresponds to a process in the sense of a set of process instances, not to a single process instance*. Business objectives are thus always subject to cardinality and time constraints[5] – a real-world business objective for a business process is achieved when a number of process instances are successfully enacted within a certain timeframe. A single successfully enacted process instance will usually not suffice to achieve a business objective, but merely raise the number of successful instances by one towards the required cardinality.
2. For a business process and its associated business objective, there must be a direct causal relation between the contribution of the business process and the achievement of the business objective.

The first requirement is instrumental. Note that, according to Definition 1, we need to assess resource consumption caused to achieve the business objective. If we cannot determine whether the business objective has been achieved, this is not feasible. The second requirement is more relaxed than the WfMC business process definition where a business process realises a business objective instead of merely contributing to one. However, business objectives where more than one business process contribute are also conceivable. In this case, the business

[5] We can safely assume that there are no business objectives that do not comprise a time constraint - in an extreme case, the time constraint would be the period of operation of the organisation. Note that time constraints may be given in cyclic (i.e. repetitive) or due date form. Due to the mostly repetitive nature of business processes subject to systematic quality management, the former usually predominates.

objective can easily be broken down to sub-objectives where each reflects just the contribution of one process. It is also possible to have a business process that contributes to multiple business objectives, but these can be combined into a single one, as we will see in our adapted business objectives ontology. In any case, a causal link needs to be established: if the business process's causal contribution towards its business goal cannot be established, it possibly constitutes a waste of resources where no quality definition can be applied.

The second requirement entails that only operational business objectives that can be fully controlled by the organisation are valid; i.e. strategic objectives (e.g., in the sense of competitive positioning as in [39]) are exempt. To illustrate the difference, consider the following example: A strategic objective for an organisation might be to extend its market share. However, even if this goal is reached, it is not possible to determine for any one process in the organisation whether its execution was really required. For instance, the weakness of competitors might have played a role as well. Moreover, one would be hard-pressed to describe a business process where this could be given as the business objective according to the WfMC definition. This is also reflected in the phrasing of Definition 1.

Example 2. As an example for valid business objectives, consider the helpdesk process of an internet service provider:

- "Improve customer satisfaction" would not constitute a valid business objective because, without additional information, one cannot determine whether or not the objective has been achieved. Additional information required comprises a definition of how customer satisfaction is measured as well as as-is customer satisfaction.
- "Achieve 95% customer satisfaction" would not constitute a valid business objective because no clear causal link to any business process can be established. The level of customer satisfaction is a product of multiple business processes as well as external factors – we have no way of knowing whether 95% customer satisfaction is due to an effective helpdesk process or to anything else, so it does not make sense to use this as a determinant for helpdesk process quality.
- "Solve all incoming customer tickets within two business days" or, more precisely, "All incoming customer tickets have been solved within two business days" would constitute a valid business objective as it clearly describes a measurable state of the organisation to be reached via the business process.

In our definition of fundamental business process quality, we also stipulated that the business objective is given a priori, i.e., business process quality cannot be improved by achieving a more desirable (or, higher quality) business objective. For our helpdesk example, this means that a process that solves all customer tickets within two days while consuming the same amount of resources is not considered as of higher quality than the 95%-process. As this result may be irritating at first, we reconsider the ISO quality definition: requirements cannot be "over-achieved". Moreover, treating the business objective as a factor in determining a process's quality would preclude quality measurement of any sort. For instance, delivering higher data rates might be even more desirable than 100% ticket resolution: generally, there is no natural limit to optimising business objectives, so assessing business process quality under consideration of the business objective would incorporate comparison to a hypothetical optimum objective that eludes analytic appraisal. For a more detailed discussion of this issue, refer to Appendix A.

5.1.2 Related Work on Business Objectives

We are now able to discuss related work on business objectives in BPM based on our requirements. Models for business objectives or goals[6] have been proposed by Kueng and Kawalek [40], Neiger and Churilov [41,42], Soffer and Wand [43], Markovic and Kowalkiewicz [44] as well as Lin and Sølvberg [45] based on previous work [46]. All approaches implicitly or explicitly recognize differences between strategic and business objectives. Results are summarised in Table 3.

As none of the approaches we discussed focuses on quality- or effectiveness-related issues, it is not surprising that none fully matches our requirements. For our purposes, we therefore adapt the approach of Lin and Sølvberg [45] which has the additional advantage of being designed to accomodate the semantic needs of distributed process models. This property might be useful when, as part of future work, an attempt is made to automate business process quality evaluation independently of single process modeling languages.

5.1.3 Adapted Business Objectives Ontology

The main topic we need to resolve results from the focus of Lin and Sølvberg's work on enabling collaboration in distributed process landscapes (e.g. cross-organisational process choreographies) by annotating semantic content to process models [46,45]. This implies that considerations are made on a modeling instead of an enactment level. Accordingly, their ontology does not comprise a concept for cardinality which will be required to satisfy our first requirement towards valid business objectives. More specifically, we need to provide for the notion of business objectives being achieved by sets of process instances instead of individual process instances as discussed above. Additionally, we will need to elaborate on the concept of constraints posed towards objectives.

To reflect the understanding of business processes set out in Section 3.1 and the requirements discussed above, we adapt and extend the goal ontology proposed by Lin and Sølvberg in [45] to a business objective ontology. To accomodate our requirements, we undertake the following alterations:

[6] In the following, we only use the term business objectives while related work might also refer to business goals. In the BPM space, these terms are generally used synonymously.

Source	*Primary focus*	*Strategic objectives*	*Business objectives*	*Requirement for measurable definition*	*Requirement for causal relation*
Kueng and Kawalek	Modeling business processes based on goals and evaluating business process design	"Non-functional goals" independent of any single business processes	"Functional goals" used as the basis for business process modeling	*Not fulfilled:* no formal measurable definition of objectives	*Fulfilled:* business processes are designed based on objectives to be achieved
Neiger and Churilov	Applying the value-focused thinking approach [47] to structure business objectives for business process modeling	"Strategic objectives", presumably corresponding to top-level objectives within a hierarchy of "fundamental objectives"	"Functional or process objectives" as means objectives contributing to fundamental objectives of the organisation "Functional objective" denotes the objective of a function in the sense of an atomic functional node within an EPC	*Not fulfilled:* no requirements posed towards how a business objective must be specified	*Partially fulfilled:* formal link between processes and objectives, but no causal relation required
Soffer and Wand	Incorporating business processes' contribution towards "soft goals" into business process modeling by formalizing concepts and interrelations	"Strategic goals [...] more abstract objectives the organization is striving to achieve", corresponding to "soft goals" to evaluate process alternatives	"Operational goals, defining a desired state to be reached by a process" Every process instance terminates in a state that belongs to the process goal	*Partially fulfilled:* a process goal is defined as any state a respective process instance can terminate in. We therefore can determine when a process goal has been achieved, but lack the concept of a process as a set of multiple process instances with a common objective	*Fulfilled:* the goal is defined as the set of states a process instance can terminate in, "all goal-defining state variables are changed from their initial value at least once in at least one path of the process"
Markovic and Kowalkiewicz	Integrating business goals into business process modeling	"A strategic goal tends to be longer term and defined qualitatively"	"An operational goal is a short-term contribution to a strategic goal"	*Fulfilled:* goals are defined as "an attainable, measurable and time-bound state of the world"	*Partially fulfilled:* goals are formally linked to business processes, but the causal relation between executing the process and achieving the goal is not formalised
Lin and Sølvberg	Developing a goal ontology for semantic annotation of distributed process models	"Soft goals can be positively or negatively satisfied by [..] activities"	"Hard goals can be achieved by [..] activities"	*Partially fulfilled:* goals are expressed with respect to states of activities or artifacts; however, there is no concept of multiple process instances contributing to a single business objective	*Fulfilled:* goals are explicitly linked to activities that achieve them

Table 3. Views on business objectives in BPM

- The term “goal” is replaced by “business objective” to be consistent to the WfMC definition of business processes.
- A business objective reflects a desired state of the organisation. It is composed of artifacts in desired states with respect to the values their attributes assume and the satisfaction of additional constraints. This presumes that attributes of artifacts are modeled in a way that they are apt to completely describe desired states. This understanding is central to our approach. Generally, achieving a business objective will require more than one successful process instance.
- Activities are omitted from the targets of business objectives because executing an activity does not constitute a target in itself from a business perspective. It might rather be stipulated that a certain *class* of activities must be executed to achieve a certain result which, in turn, is part of the objective. In other words, the activity’s result, but not the activity in itself is part of the business objective. We choose to model this as constraints to the desired artifact states (see below). Consider the following example: when handling incoming materials, it may initially constitute a goal to have checked the materials for defects. From a business perspective, however, it is not desirable to check materials, but to ensure that defects are detected with a certain level of certainty (i.e. that the expected probability of a false acceptance or “β error” is below a certain threshold value). Whether this is achieved by the concrete checking activity or by anything else does not matter: all activities that result in the required level of certainty are equivalent from an objectives perspective. This can be modeled as a *checked* attribute of the material artifact with a constraint of a given level of certainty.
- Similarly, constraints are omitted as direct target of business objectives. For our purposes, business objective constraints generally relate to attributes of artifacts, to the quantity of artifacts or to a timeframe, and are modeled as such. If additional constraints are to be satisfied, they are therefore modeled with reference to attributes.
- To achieve a more rigorous definition of business objectives, we replace the unspecified relation between business objectives and (target) artifacts. Instead, our model explicitly represents artifacts’ residing in desired or undesired states.
- We omit the concepts of soft versus hard goals as well as actor roles as these are not central to our approach at this stage.

The resulting business objective ontology is depicted in Figure 2. The notation used has been described in [48].

- A Business Objective is constituted by a non-empty set of Artifact Targets.
- An Artifact Target refers to exactly one Artifact Type. This relation is subject to a Cardinality constraint and a Timeframe constraint modeled as attributes to the Artifact Target. Basically, the Artifact Target can be interpreted as part of the Business Objective that demands that a certain number

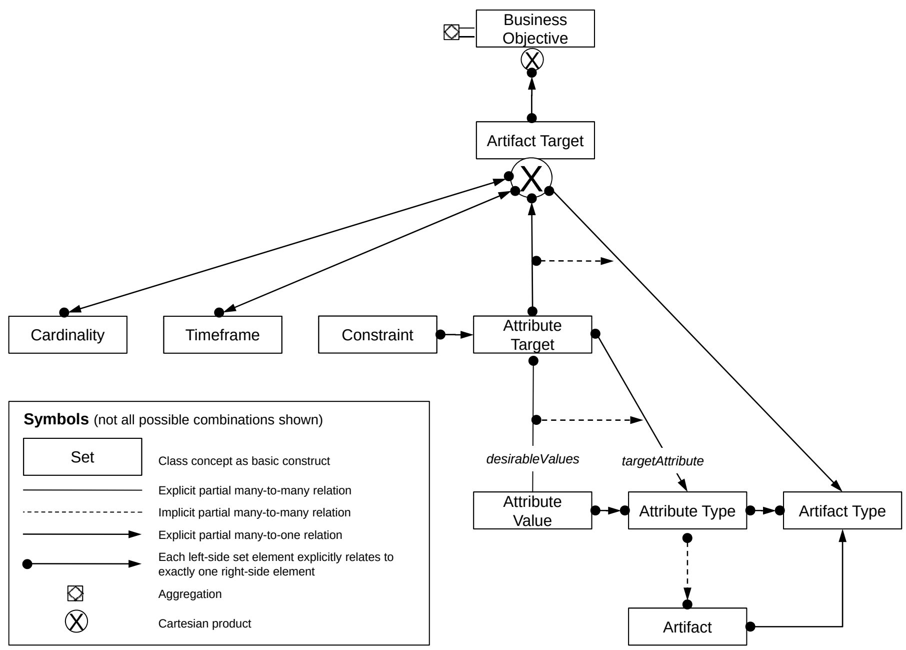

Fig. 2. Business objectives ontology

of Artifacts of a certain type are available in a certain state within a certain Timeframe. As an example, consider a number of incoming payments that should be posted within a week.

– As in the model proposed by Lin and Sølvberg, Business Objectives can be nested. Following the WfMC definition which links each business process to a business objective, we can easily aggregate and disaggregate business processes in the same way as business objectives without violating the WfMC or other common definitions. Therefore, it will be a subject of future work to assess if there are any sensible rules on how this should be done or if the structuring of Business Objectives can be done arbitrarily.
– The Cardinality of the Artifact Target should be specified as a relation and a quantity, e.g. "> 5" while the quantity might also depend on other Business Objectives, processes within a superordinate process chain or case occurrences, e.g. the number of incoming payments. If the Cardinality is based on case occurrences, additional specification (e.g. of a related timeframe) is required. The Timeframe of the Artifact Target will in most cases be specified in relative terms, e.g. "within one week". As most processes subject to BPM are repetitive in nature, absolute Timeframes like "by 31/12/2010" will be the exception.
– Each Artifact has attributes according to Attribute Types defined via its Artifact Type. We assume that there is at least an "ID" attribute we can use to determine whether an Artifact exists, so there will be no Artifacts without attributes. There is an implied one-to-many relation between Artifacts and Attribute Types. Each Attribute Type is associated to a set of specific Attribute Values which represent the possible values an attribute of the Attribute Type might assume.
– For each Artifact Target, there is a set of Attribute Targets. Attribute Targets related to a common Artifact Target may only relate to Attribute Types associated with the Artifact Target's Artifact Type. In other words, they must be consistent to the Artifact Type of the Artifact Target. This is represented by an implicit relation between the Artifact Target-Attribute Target and the Artifact Target-Artifact Type relations.
– Each Attribute Target is associated with a sub-set of the Attribute Values of its Attribute Type. These represent the "desirable values" that must be achieved to promote the Attribute Target and ultimately the Artifact Target to a desired state.
– An Attribute Target may be associated with additional Constraints that represent how the Attribute Target should be reached. As stated above, a good example for this is the level of certainty associated with "checked" attributes.

Note that the composition of business objectives from Artifact Targets readily supports breaking down and combining business objectives as set out in Section 5.1.1 by splitting and joining their sets of Artifact Targets.

Example 3. Our business objective ontology can, for instance, be applied to the helpdesk case from Example 2. In this case, our Business Objective is to solve all incoming customer tickets within two days. This means that we need to consider a single Artifact Target with "customer ticket" as its Artifact Type and a single Attribute Target with "solution approved by customer" as its Attribute Type. The single desirable Attribute Value is "true". The sole challenge to model this business objective lies in the Cardinality of its Artifact Target. Apparently, "all incoming customer tickets" relates to case occurrences we need to specify further. In this case, we can refer to the Timeframe of two business days. In practical terms, it makes sense to collect all tickets of a business day as they relate to a common absolute Timeframe of two business days later, so the number of case occurrences within a business day provides the Cardinality of the business objective. Note that we thus formally work with a different Business Objective per business day! This issue will be subject to further discussion in future work.

5.1.4 Business Objective Achievement

In summary, we can now define when a Business Objective has been achieved:

Definition 2. *Achievement of a Business Objective bo is defined as follows:*

$$
\begin{aligned}
achieved\,(bo) \Leftrightarrow & \forall at \in bo : \\
& \big(\exists A \mid \big(\forall a \in A : \Lambda_a = \Lambda_{at} \wedge \forall att \in ATT_{at} : v_a^{\lambda_{att}} \in AV_{att}\big) \wedge (\mid A \mid rel_{at}\; c_{at})\big) \wedge \\
& satisfied\,(t_{at})
\end{aligned}
$$

where

bo and at	*denote a Business Objective and an Artifact Target,*
A and a	*denote a set of Artifacts and a single Artifact,*
Λ_a *and* Λ_{at}	*denote the Artifact Type of an Artifact a and the Artifact Type associated with an Artifact Target at,*
att and ATT_{at}	*denote an Attribute Target and the set of Attribute Targets associated with an Artifact Target at,*
λ_{att}	*denotes the Attribute Type associated with an Attribute Target att,*
$v_a^{\lambda_{att}}$	*denotes the value of the attribute of an Artifact a with Attribute Type* λ_{att}*,*
AV_{att}	*denotes the set of desirable Attribute Values associated with an Attribute Target att,*
rel_{at} *and* $c_{at} \in \mathbb{N}$	*denote the relation associated with the Cardinality of an Artifact Target at and the quantity associated with the Cardinality of an Artifact Target at, while*
$satisfied\,(t_{at})$	*signifies that the the timeframe constraint* t_{at} *of an Artifact Target at is satisfied.*

As additional prerequisite, a Business Objective bo is only valid iff the following holds:

$$\forall att \in ATT_{at} : (\Lambda_{\lambda_{att}} = \Lambda_{at} \wedge \forall av \in AV_{att} : \lambda_{av} = \lambda_{att})$$

where, in addition to the definitions stated above, $\Lambda_{\lambda_{att}}$ denotes the Artifact Type associated with the Attribute Type λ_{att} of Attribute Target att. In other words, all Attribute Targets associated with an Artifact Target must (indirectly) refer to the correct Artifact Type, and all Attribute Values associated with an Attribute Target must refer to the correct Attribute Type.

Note that business objective achievement is defined binomially, i.e. there is no grade to which an objective has been achieved, for instance in the sense of a share of successfully completed transactions. This is due to the fact that gradual achievement of business objectives would presume equal importance between all Artifact Targets and between all individual Artifacts, which we cannot take as granted generally.

We have now reached a measurable definition of when a business objective has been achieved. For our second requirement with respect to valid business objectives, we refer to the integration of process models and the goal ontology as described by Lin and Sølvberg, which clearly establishes a causal link and satisfies our needs without further amendments.

We recognise that this rather mechanistic approach towards business objectives is not sufficient to entirely capture soft goals as described in [43] as well as desirable or undesirable "side effects" of business process execution, such as employees' satisfaction, which might also be denominated as objectives for business processes. In our approach, these effects need to be integrated into the Constraints associated with Attribute Targets or the evaluation of resources consumption as discussed in Section 5.2. However, a more practical approach to these issues may be to accept that not all an organisation strives for is fit to be expressed in terms of business processes. A discussion on related topics can be found in Appendix A.

5.2 Economic Value Consumption

Having defined under which conditions a business objective can be considered as having been achieved, we now look into the second component of Definition 1: the consumption of economic value caused by a business process to achieve its business objective. We first compare the concepts of economic value consumption in business processes and business process input. We then examine the various types of economic resources consumed by a business process as well as the corresponding unit costs. Lastly, we discuss optimum economic value consumption and waste in business processes as a proxy measure to be applied instead of comparing actual and optimum value consumption.

5.2.1 Economic Value Consumption versus Business Process Input

Business process input is one of the most widely-used terms in BPM, and is also closely linked with the economic value consumed by business processes. We therefore assess the scope of business process input versus the topics we consider as valuable economic resources consumed in business processes. An initial overview is given in Figure 3.

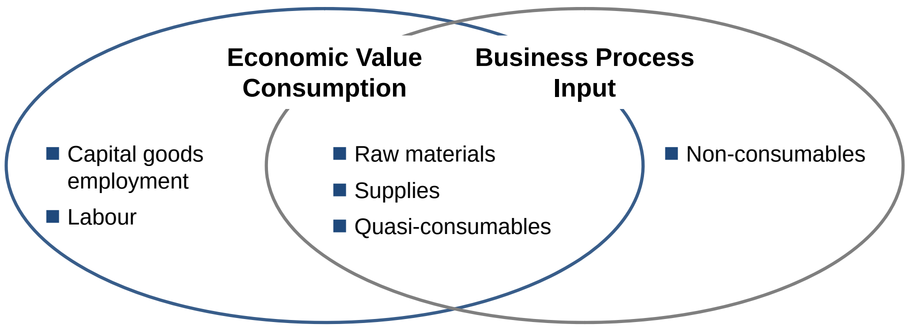

Fig. 3. Economic value consumption vs. business process input

The resources that constitute economic value consumption will be discussed in more detail in the next section, including resources that are used and completely or partially consumed in business processes, but not typically considered as business process input. Here, we only describe non-consumables as the part of business process input we do not regard as constituent of economic value consumption.

In our understanding, non-consumables comprise any tangible and intangible resources that are utilised, but not consumed by a business process. As an example, take information provided by an upstream process or plots of land. However, we need to discern between "core" non-consumables and quasi-consumables. Quasi-consumables are non-consumables which should be treated as consumables with respect to economic value consumption. This occurs when non-consumables are procured or produced (as output or business objective of upstream processes) exclusively for utilisation in the business process under consideration. In this case, the respective upstream process can be seen as part of the business process in question, and procured non-consumables can be seen as equivalent to raw materials or supplies if they are used in individual process instances or as capital goods if they are used for the process as a whole.

In the following sections, resources whose employment in business processes leads to economic value consumption will be referred to as economic resources.

5.2.2 Types of Economic Resources in Business Processes

The total economic value consumption caused by a business process can be decomposed as depicted in Figure 4. White boxes represent actual classes of economic resources consumed by the process while grey boxes provide additional levels on which these can be aggregated. The economic resources consumed in business processes are presented in Table 4 with respect to their usage that in turn leads to required quantities.

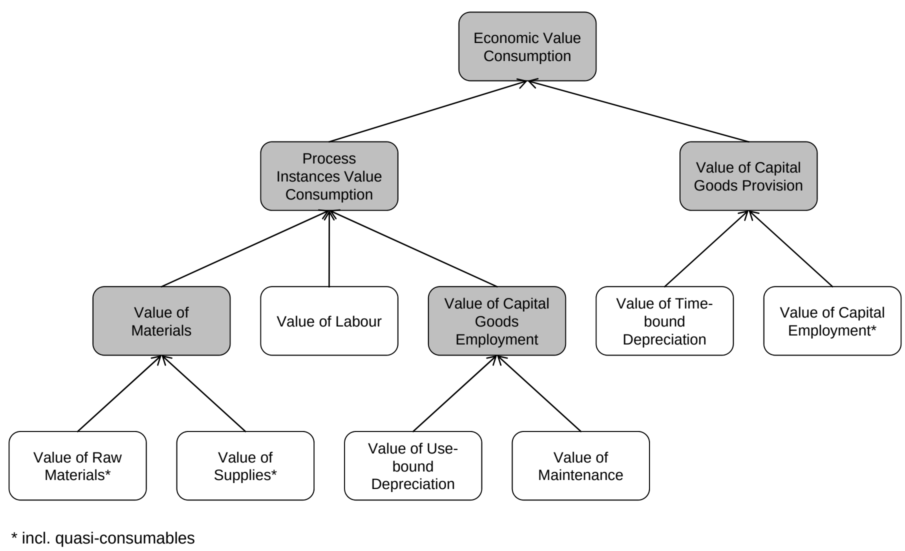

Fig. 4. Economic resources tree

Note that according to the common use of the term in economics, raw materials assume a special role in economic value consumption as they are directly "incorporated" into the business objective. This means that there is a natural lower limit to the raw materials required to achieve a business objective. Transgressing the natural lower limit of raw materials consumption is caused by process instances that lead to refuse (i.e. the raw material consumed by the respective instances is wasted) or a process design that deliberately uses excess raw material per process instance e.g. for cutting scrap (i.e. each process instance uses more raw material than strictly required due to process design).

Two additional aspects will be referred to future work: Process follow-up costs are costs which are caused by process execution but occur later on, such as the cost of non-compliance to external regulations. In many cases, follow-up costs are related to risks incurred in the course of process exeuction. Follow-up costs are akin to negative externalities in economics [49]. Sunk costs are costs that cannot

Economic Resource	*Description and Usage*
Process Instances Value Consumption	This category consists of resources that are consumed in individual process instances; i.e. if there are no process instances, the resources are not consumed. Note that resource consumption need not be equal for each process instance, so the number of process instances is only an approximate measure.
Materials	Materials correspond to goods that are spent during the execution of process instances. Mostly, this relates to tangible goods, but we also need to treat some quasi-consumables in a similar way. This occurs when information items are not spent by a process instance, but when they have been created or procured exclusively for the use of the process instance.
Raw materials	Raw materials directly enter into the output of a business process. Therefore, they are directly linked to the business objective of a business process (e.g. if there is a bill of materials) unless they are employed ineffectively. Sources of waste consist of used raw materials that are not required according to the business objective ("over-achieving" the business objective) and rejects.
Supplies	Supplies comprise materials that are employed and consumed (or quasi-consumed) in a business process, but do not enter into the business process output. As an example, consider power usage by machinery during process execution.
Labour	Cost is caused by personnel spending time to work on a process or to attend to a process. Labour thus incorporates characteristics of materials usage as well as capital goods employment or even capital goods provision, as costs may arise because personnel is kept ready, even if there is no work to be executed on the process.
Capital Goods Employment	Generally, the employment of tangible capital goods in process instances causes costs. Intangible capital goods will cause costs as they are provided (see below), but not as they are employed.
Use-bound Depreciation	Tangible capital goods may deteriorate as they are used, i.e. they may be subject to wear.
Maintenance	The use of tangible capital goods may lead to the need to execute ongoing maintenance processes which, in turn, causes costs.
Capital Goods Provision	Employing capital goods in business processes will cause costs even if the resources are not used in process instances, but simply as they are held ready for use. Therefore, these costs arise independently of how many process instances are executed.
Time-bound Depreciation	Capital goods may also deteriorate in value as time passes, independently of their being used.
Capital Employment	Holding ready capital goods will bind economic capital causing opportunity costs.

Table 4. Types of economic resources

be avoided anymore, i.e. that occur regardless of whether or not a process is actually executed. This is mostly the case if resources are made dedicated to a process, such as capital goods that are procured and cannot be utilised otherwise.

5.2.3 Unit Costs

To determine the economic value consumed, we also require unit costs. We refer to unit cost in the economic sense; i.e., unit costs describe appropriate economic costs that may or may not correspond to price. In this respect, we need to consider several issues. Generally, resources might be valued at actual costs or at opportunity costs. Opportunity costs describe the value that is lost because resources are not employed otherwise, e.g. used in other processes that may generate additional economic value. Opportunity costs are very similar to alternative business objectives and are therefore not considered in our context (see Appendix A) – we can assume zero elasticity of supply with respect to resources employed, which means that resources can be procured or produced as required without change in price or costs. However, the actual cost of resources must also be subject to closer discussion as it is affected by upstream processes (e.g. in procurement or the choice of location for labour). We defer this question to later work. For capital goods, depreciation is traditionally valued via acquisition costs and useful life (mostly external accounting, see for instance IAS 16 [50]) or replacement costs and useful life (internal accounting). Both pose similar issues as actual costs for other resources.

The determination of unit costs is a major driver of complexity for business process quality assessment as differing methods and therefore differing results lead to shifts in the relative weighing of resources with respect to their influence on overall business process quality. As example consider the use of capital goods such as information systems enabling process automation. In a high labour cost environment, it may be an economically sound decision to spend capital on additional process automation while this may not be sensible anymore if process execution is relocated e.g. to an offshore low cost environment.

5.2.4 Optimum Economic Value Consumption and Proxy Measures

According to Definition 1, we will not only require an understanding of the economic value of resources consumed by a business process to assess its quality, but also of optimum (i.e. minimum) value consumption required in case of an optimum process to achieve the process's business objective. In the following, we refer to a business process that is effective with respect to a given business objective and optimal with respect to its economic value consumption as a comparable optimum process. According to Definition 1, a common business objective is the only limitation that needs to be observed to consider a hypothetical business process as comparable to an actual one.

Even for simple business objectives, it will in practice be very difficult, if not impossible, to determine minimum economic value consumption with a comparable optimum process. The first reason for this is that it is difficult to evaluate economic resource consumption for a comparable optimum process as well as for an actual process. The second reason is that neither the comparable optimum process design nor the comparable optimum settings for process execution are known. This issue is exacerbated with added "degrees of freedom" with respect to process design and alterations to the execution environment of the business process that might be made to obtain a comparable optimum process. Process design determines the activities to be executed as part of the process and thus the economic resources required. The process execution environment comprises external suppliers, upstream business processes, availability of capital goods, and unit labour costs (e.g. via the choice of location). It thus determines unit costs for economic resources. Each dimension will need to align to the other one in order to sustain an optimum balance. For instance, if the process execution environment is changed to a low labour cost location, process design may have to be realigned to substitute the use of capital goods with labour. It becomes clear that there is no singular optimum process design and no singular optimum process execution environment – both dimensions depend on each other.

As already touched upon in Section 4, in this respect our approach will be to assess appropriate scopes of influence or domains for differing BPM lifecycle stages in the course of future work. This will not only provide us with clear organisational responsibilities, but also enable us to at least partially resolve the degrees of freedom issue by constricting the frame of action available on each stage. Basically, the limitations to be observed in the definition of a comparable optimum process become more severe as we progress in the BPM lifecycle because the degrees of freedom available diminuish. In particular for the lower-level stages, this will lead to examining sources of economic waste that can be allocated to the respective stage as a proxy measure from deviations from a comparable optimum process. For example, on the lifecycle stage for actual process execution, there might be deviations from the optimum in the form of resource waste that could be avoided by more diligent work. However, resource unit costs are generally not in the responsibility of the respective organisational roles.

6 Related Work

We already touched upon major related work with respect to basic aspects of QM and BPM in Section 3. Existing approaches on business objectives as a prerequisite for business process quality assessment were discussed in Section 5.1.2.

There is some related work that deals with the quality of business process models: van der Aalst introduced soundness of Workflow Nets [51], Weber and Reichert developed process model refactoring [52], Li and Reichert addressed reference model discovery by model merging [53], Becker et al. discussed process model quality focusing on certain stakeholder groups and applications, Gucegioglu and Demirors applied software quality characteristics to business processes [54], Mendling assessed formal errors in EPC business process models [55], Cardoso analysed workflow complexity as one possible measure for process model quality [56], and Vanderfeesten et al. discussed quality metrics in business process modeling [57,58]. As all of these approaches are related to business process design, we will refer to them in our future discussion of quality on differing BPM lifecycle stages. However, we need to be aware that these approaches are all based on individual quality drivers or characteristics. They are not formally derived from a comprehensive definition of business process quality, but rather aimed at covering single aspects of business process *model* quality in detail. Our approach intends to complement this work with a comprehensive framework for business process quality as a whole.

A more comprehensive attempt to develop a "Quality of Business Processes (QoBP) framework" focusing on process modeling was made by Heravizadeh et al. [59]. Business process quality is defined in terms of 41 quality dimensions which are derived from related work, e.g. in the field of software engineering. Insofar, the approach lists quality characteristics, but does not provide a singular definition of quality which would, for instance, enable quality measurement. This also means that there is no way to clearly establish why each quality dimension is important, in which way it contributes to overall quality or if the listed quality dimensions are sufficient to explain overall quality. In our approach, we intend to address these issues by first providing a well-founded fundamental quality definition, and then deriving contributive characteristics in a second step. The QoBP approach has been presented in more detail in [60]. In this context, quality has been defined as non-functional but distinguishing characteristics of a business process. We do not concur with that view as we define fundamental business process quality under consideration of a business objective to be achieved. In our view, this better suits the ISO quality definition. However, we concede that non-functional characteristics are difficult if not impossible to evaluate in economic terms, so the two approaches to quality can be seen as complementary.

Heinrich and Paech also made a proposal to define the quality of business processes mostly based on insights from the field of software quality [61]. While this approach lists various quality characteristics, which may provide guidance to our future work, it does not integrate them into a comprehensive formal quality definition. Therefore, it is not yet apt to fulfil our measurability requirement. Moreover, we stipulate that the adoption of software engineering results to business process problems still requires closer analysis.

Business process reengineering and optimisation constitutes an area which, taking our value-based fundamental definition, is closely related to optimising business process quality. [19,18] provide good examples for the "classic" all-encompassing reengineering view. Reengineering approaches mostly comprise recommended best practices and other informal methods which are mostly based on anecdotal evidence (see the sample case in Appendix B). [62,63,64,65] and, with a focus on well-defined process models, [66] constitute additional good examples for optimisation based on informal methods. This view is also reflected in the OMG Business Process Maturity Model [67] and other BPM maturity models [68] which suggest criteria to allocate business processes to maturity levels without giving clear evidence on how this structure is devised. While this informal character fits well with practical applicability on the one hand, we still lack an overarching comprehensive model to ensure causal relations between measures recommended and intended results as well as completeness of coverage of quality or optimisation aspects. From our perspective, this may be addressed by structuring measures along our fundamental definition and BPM lifecycle stages which will be attempted in future work. The other class of related optimisation approaches focuses on the analysis of formalised business processes or workflows. Examples include [69,51], where Petri nets are proposed to leverage existing analysis methods, and [70], where various optimisation strategies for process designs with given input and output sets per activity are discussed. These approaches are mainly suited to optimising control flow and resource scheduling, as they typically do not address individual activities in terms of necessity, effort or possible alternatives. They thus constitute important tools but are not sufficient to guarantee optimum business process design. We intend further analysis to be part of future work on quality in the process design lifecycle stage.

Process performance management and business activity monitoring constitute another related area linked to the quality of process execution. Research in this area is very much driven by practical requirements, and we will refer to it in a future discussion on quality on the process execution lifecycle stage. Exemplary work includes [71,72] and reflects the close association of this research issue to industry and tool vendors. Also in the field of process execution, Grigori et al. have developed a proposal to monitor and manage exceptions in process execution [73]. We will refer to this in our later research on the respective BPM lifecycle stage.

7 Conclusion

In this paper, we specified requirements with respect to the practical applicability of business process quality measures. We discussed existing views on business processes and approaches to quality. We derived a fundamental business process quality definition that satisfies both fields, but will require further detailing to achieve practical applicability. However, this constitutes a framework to guide further research and to appraise related approaches – which are mostly focused on particular aspects – in a broader context. The components of our fundamental definition were assessed in more detail to identify areas where additional work will be required. This provides us with a sound basis from which we can extend our work in the field of quality management for business processes.

Future research will focus on business process quality measures that are founded on our fundamental definition from Section 4 and fulfil the requirements set out in Section 2. As set out above, a major issue in this respect relates to assessing various BPM lifecycle stages regarding business process quality. Other fields to be examined comprise the identification of resources waste or optimum comparable processes as well as practical evaluation of economic value consumption. Process follow-up costs and sunk costs have already been mentioned as exemplary for this field. We also intend to analyse how business processes and business objectives should be structured to enable effective quality assessment. The reason for this is that, based on common business process definitions, process models may be arbitrarily aggregated or decomposed, e.g. to obtain well-manageable process documentation. We intend to analyse how the impact of this on quality assessment results can be eliminated or at least minimised. Defining business objective cardinalities in case of recurring transactional processes has already been mentioned in this respect (see Example 3). Finally, the integration of QM in BPM support tools will be an important issue for practical application.

References

1. Phillips, L.W., Chang, D.R., Buzzell, R.D.: Product quality, cost position and business performance: A test of some key hypotheses. Journal of Marketing **47**(2) (Spring 1983) 26–43
2. Capon, N., Farley, J.U., Hoenig, S.: Determinants of financial performance: a meta-analysis. Management Science **36**(10) (October 1990) 1143–1159
3. Forker, L.B., Vickery, S.K., Droge, C.L.: The contribution of quality to business performance. International Journal of Operations & Production Management **16**(8) (1996) 44–62
4. Adam, E.E., Corbett, L.M., Flores, B.E., Harrison, N.J., Lee, T., Rho, B.H., Ribera, J., Samson, D., Westbrook, R.: An international study of quality improvement approach and firm performance. International Journal of Operations & Production Management **17**(9) (1997) 842–873
5. Dale, B.G., van der Wiele, T., van Iwaarden, J., eds.: Managing Quality. 5th edn. Wiley-Blackwell (2007)
6. Parasuraman, A., Zeithaml, V.A., Berry, L.L.: A conceptual model of service quality and its implications for future research. Journal of Marketing **49**(4) (1985) 41–50
7. Harvey, J.: Service quality: a tutorial. Journal of Operations Management **16**(5) (1998) 583–597
8. Porter, M.E.: Competitive Advantage: Creating and Sustaining Superior Performance. Free Press, New York (1985)
9. Miller, J.G., Vollmann, T.E.: The hidden factory. Harvard Business Review **63**(5) (September-October 1985) 142–150
10. Emore, J., Ness, J.: The slow pace of meaningful change in cost systems. Journal of Cost Management **5**(4) (1991) 36–45
11. Küting, K., Lorson, P.: Grenzplankostenrechnung versus Prozeßkostenrechnung (in German). Der Betriebs-Berater **21** (1991) 1421–1433
12. Deming, W.E.: The new economics: for industry, government, education. 2nd edn. MIT Press (2000)

13. Sousa, R., Voss, C.A.: Quality management re-visited: a reflective review and agenda for future research. Journal of Operations Management **20**(1) (2002) 91–101
14. Crosby, P.B.: Quality is free: the art of making quality certain. New American Library (1980)
15. International Accouting Standards Board: Framework for the Preparation and Presentation of Financial Statements (1989) `http://eifrs.iasb.org/eifrs/bnstandards/en/framework.pdf`, accessed on 13/04/2010.
16. Davenport, T.J., Short, J.E.: The new industrial engineering: Information technology and business process redesign. Sloan Management Review (Summer 1990) 11–27
17. Hammer, M.: Reengineering work: don't automate, obliterate. Harvard Business Review (July-August 1990) 104–112
18. Davenport, T.J.: Process innovation: reengineering work through information technology. Harvard Business School Press (1993)
19. Hammer, M., Champy, J.: Reengineering the corporation. A manifesto for business revolution. HarperBusiness (1993)
20. Lindsay, A., Downs, D., Lunn, K.: Business processes – attempts to find a definition. Information and Software Technology **45**(15) (December 2003) 1015–1019
21. van der Aalst, W.M.P., Berens, P.J.S.: Beyond workflow management: product-driven case handling. In: Proceedings of the 2001 International ACM SIGGROUP Conference on Supporting Group Work, ACM (2001) 42–51
22. Workflow Management Coalition: Workflow management coalition terminology & glossary 3.0 (February 1999) `http://www.wfmc.org`, document reference WFMC-TC-1011, accessed on 03/11/2009.
23. Weske, M.: Business Process Management. Springer (2007)
24. Dale, B.G.: The Received Wisdom on TQM. In: Managing Quality. 5th edn. Wiley-Blackwell (2007) 58–73
25. International Organization for Standardization: ISO 9000:2005: Quality management systems – Fundamentals and vocabulary (2005)
26. Guler, I., Guillén, M.F., Macpherson, J.M.: Global competition, institutions, and the diffusion of organizational practices: The international spread of ISO 9000 quality certificates. Administrative Science Quarterly **47**(2) (June 2002) 207–232
27. Neumayer, J., Perkins, R.: Uneven geographies of organizational practice: explaining the cross-national transfer and diffusion of ISO 9000. Economic Geography **81**(3) (2005) 237–259
28. International Organization for Standardization: The ISO Survey - 2007 (2008) `http://www.iso.org/iso/survey2007.pdf`, accessed on 05/04/2010.
29. Garvin, D.A.: What does "product quality" really mean? Sloan Management Review **26**(1) (Fall 1984) 25–43
30. Garvin, D.A.: Competing on the eight dimensions of quality. Harvard Business Review **65**(6) (1987) 101–109
31. Sower, V.E., Fair, F.K.: There is more to quality than continuous improvement: listening to Plato. Quality Management Journal **12**(1) (2005) 8–20
32. van der Aalst, W.M.P., ter Hofstede, A.H.M., Weske, M.: Business process management: A survey. In van der Aalst, W.M.P., ter Hofstede, A.H.M., Weske, M., eds.: International Conference on Business Process Management 2003. Volume 2678/2003 of Lecture Notes in Computer Science., Springer (2003)

33. Christensen, C.M., Rosenbloom, R.S.: Explaining the attacker's advantage: technological paradigms, organizational dynamics, and the value network. Research Policy **24**(2) (March 1995) 233–257
34. Bower, J.L., Christensen, C.M.: Disruptive technologies: catching the wave. Harvard Business Review **73**(1) (January-February 1995) 43–53
35. Reeves, C.A., Bednar, D.A.: Defining quality: alternatives and implications. Academy of Management Review **19**(3) (1994) 419–445
36. Leffler, K.B.: Ambiguous changes in product quality. American Economic Review **72**(5) (December 1982) 956–967
37. Feigenbaum, A.V.: Quality control: Principles, practice, and administration. McGraw-Hill, New York (1951)
38. Drucker, P.F.: The effective executive. Harper & Row (1967)
39. Porter, M.E.: What is strategy? Harvard Business Review **November-December** (1996) 61–78
40. Kueng, P., Kawalek, P.: Goal-based business process models: creation and evaluation. Business Process Management Journal **3**(1) (1997) 17–38
41. Neiger, D., Churilov, L.: Structuring business objectives: a business process modeling perspective. In: International Conference on Business Process Management 2003. (2003)
42. Reijers, H.A., Vanderfeesten, I.T.: Cohesion and coupling metrics for workflow process design. In Desel, J., Pernici, B., Weske, M., eds.: International Conference on Business Process Management 2004. Volume 3080/2004 of Lecture Notes in Computer Science., Springer (2004)
43. Soffer, P., Wand, Y.: On the notion of soft-goals in business process modeling. Business Process Management Journal **11**(6) (2005) 663–679
44. Markovic, I., Kowalkiewicz, M.: Linking business goals to process models in semantic business process modeling. In: International IEEE Enterprise Distributed Object Computing Conference 2008. (2008)
45. Lin, Y., Sølvberg, A.: Goal annotation of process models for semantic enrichment of process knowledge. In Krogstie, J., Opdahl, A., Sindre, G., eds.: International Conference on Advanced Information Systems Engineering 2007. Volume 4495/2007 of Lecture Notes in Computer Science., Springer (2007) 355–369
46. Lin, Y., Strasunskas, D., Hakkarainen, S., Krogstie, J., Sølvberg, A.: Semantic annotation framework to manage semantic heterogeneity of process models. In Dubois, E., Pohl, K., eds.: International Conference on Advanced Information Systems Engineering 2006. Volume 4001/2006 of LNCS., Springer (2006) 433–446
47. Keeney, R.L.: Creativity in decision-making with value-focused thinking. Sloan Management Review **35**(4) (Summer 1994) 33–41
48. Sølvberg, A.: Data and what they refer to. In: Conceptual Modeling. Volume 1565/1999 of Lecture Notes in Computer Science. Springer (1999) 211–226
49. The Economist: Economics A-Z, Keyword: Externality `http://www.economist.com/research/economics/alphabetic.cfm?letter=E`, accessed on 01/04/2010.
50. International Accouting Standards Board: International Accounting Standard 16: Property, Plant and Equipment (2003) `http://eifrs.iasb.org/eifrs/bnstandards/en/ias16.pdf`, accessed on 13/04/2010.
51. van der Aalst, W.M.P.: The application of Petri nets to workflow management. The Journal of Circuits, Systems and Computers **8** (1998) 21–26

52. Weber, B., Reichert, M.: Refactoring process models in large process repositories. In Bellahsene, Z., Léonard, M., eds.: International Conference on Advanced Information Systems Engineering 2008. Number 5074 in Lecture Notes in Computer Science (2008) 124–139
53. Li, C., Reichert, M., Wombacher, A.: Discovering reference process models by mining process variants using a heuristic approach. In Umeshwar Dayal, Johann Eder, J.K.H.A.R., ed.: International Conference on Business Process Management 2009. Volume 5701 of Lecture Notes in Computer Science. (2009) 344–362
54. Guceglioglu, A.S., Demirors, O.: Using software quality characteristics to measure business process quality. In van der Aalst, W.M., Benatallah, B., Casati, F., Curbera, F., eds.: International Conference on Business Process Management 2005. Volume 3649/2005 of Lecture Notes in Computer Science., Springer (2005) 374–379
55. Mendling, J.: Detection and Prediction of Errors in EPC Business Process Models. PhD thesis, WU Wien (2007)
56. Cardoso, J.: Business process quality metrics: Log-based complexity of workflow patterns. In Meersman, R., Tari, Z., eds.: On the Move to Meaningful Internet Systems 2007. Volume 4803/2010 of Lecture Notes in Computer Science., Springer Berlin / Heidelberg (2007) 427–434
57. Vanderfeesten, I., Cardoso, J., Mendling, J., Reijers, H.A., van der Aalst, W.: Quality metrics for business process models. In: Workflow Handbook 2007. Future Strategies (2007) 179–190
58. Vanderfeesten, I., Reijers, H., van der Aalst, W.M.: Evaluating workflow process designs using cohesion and coupling metrics. Computers in Industry **59**(5) (May 2008) 420–437
59. Heravizadeh, M., Mendling, J., Rosemann, M.: Dimensions of business processes quality (QoBP). In Ardagna, D., Mecella, M., Yang, J., eds.: Business Process Management Workshops 2008. Volume 17 of Lecture Notes in Business Information Processing. (2009) 80–91
60. Heravizadeh, M.: Quality-aware Business Process Management. PhD thesis, Queensland University of Technology (2009)
61. Heinrich, R., Paech, B.: Defining the quality of business processes. In Engels, G., Karagiannis, D., Mayr, H.C., eds.: Modellierung 2010. Volume P-161 of Lecture Notes in Informatics. (2010) 133–148
62. Speck, M., Schnetgöke, N.: To-be Modeling and Process Optimization. In: Process Management: A Guide for The Design of Business Processes. Springer (2003) 135–163
63. Reijers, H.A., Liman Mansar, S.: Best practices in business process redesign: an overview and qualitative evaluation of successful redesign heuristics. Omega **33**(4) (August 2005) 283–306
64. Liman Mansar, S., Reijers, H.A.: Best practices in business process redesign: use and impact. Business Process Management Journal **13**(2) (2007) 193–213
65. Jansen-Vullers, M., Kleingeld, P., Loosschilder, M., Netjes, M., Reijers, H.: Trade-offs in the performance of workflows – quantifying the impact of best practices. In ter Hofstede, A., Benatallah, B., Paik, H.Y., eds.: Business Process Management Workshops 2007. Volume 4928/2008 of Lecture Notes in Computer Science. (2007) 108–119
66. Becker, J., Rosemann, M., von Uthmann, C.: Guidelines of Business Process Modeling. In: Business Process Management: Models, Techniques, and Empirical Studies. Volume 1806/2000 of Lecture Notes in Computer Science. Springer (2000) 241–262

67. The Object Management Group: Business process maturity model (BPMM) (June 2008) http://www.omg.org/spec/BPMM/1.0/PDF/, accessed on 09/10/2009.
68. Smith, H., Fingar, P.: Process management maturity models (July 2004)
69. van der Aalst, W.M., van Hee, K.M.: Business process redesign: A Petri-net-based approach. Computers in Industry **29** (1996) 15–26
70. Hofacker, I., Vetschera, R.: Algorithmical approaches to business process design. Computers and Operations Research **28**(13) (November 2001) 1253–1275
71. Castellanos, M., Casati, F., Dayal, U., Shan, M.C.: A comprehensive and automated approach to intelligent business processes execution analysis. Distributed and Parallel Databases **16**(3) (November 2004) 239–273
72. IDS Scheer: Process intelligence white paper: What is process intelligence? (January 2009) http://www.process-intelligence.com, accessed on 07/04/2010.
73. Grigori, D., Casati, F., Dayal, U., Shan, M.C.: Improving business process quality through exception understanding, prediction, and prevention. In Apers, P.M.G., Atzeni, P., Ceri, S., Paraboschi, S., Ramamohanarao, K., Snodgrass, R.T., eds.: Proceedings of the 27th International Conference on Very Large Data Bases 2001, Morgan Kaufmann (2001) 159–168
74. Cao, G., Clarke, S., Lehaney, B.: A critique of BPR from a holistic perspective. Business process management journal **7**(4) (2001)
75. Hammer, M.: The process audit. Harvard Business Review (April 2007) 111–123
76. Thommen, J.P.: Gabler Wirtschaftslexikon, Keyword: Wirtschaftlichkeitsprinzip (2010) http://wirtschaftslexikon.gabler.de/Archiv/8349/wirtschaftlichkeitsprinzip-v5.html, accessed on 05/01/2010, in German.

A Business Objectives as Drivers of Business Process Quality?

In our fundamental business process quality definition, we stipulated that business process quality can only be established with respect to a given business objective. Moreover, we only need to determine whether a business objective has been reached, not how sound, important or desirable the business objective is for the organisation. This, in turn, means that optimising the business objective will not lead to superior business process quality, or that we can denote a business process's quality as "good" even if we do not accept the business objective pursued as sensible – an assertion that might seem surprising at first. To obtain a better understanding, we investigate three topics in this respect: quality views as discussed in Section 3.2, views on business process design and optimisation and implications from treating business objectives as variable for quality assessment.

A.1 Quality Views with Respect to Business Objective Optimization

The view that business objectives do not constitute an object for quality assessment corresponds well with the manufacturing-based approach to quality and with the ISO quality definition, which stipulates that requirements are to be achieved but does not challenge the requirements themselves. With respect to the other quality views, we must conclude that the role of business objectives in our fundamental quality definition does not fit too well with them. In the following, we will therefore need to substantiate why we preclude alternative interpretations.

A.2 Business Objectives as an Object for Business Process Design

According to our definition, setting effective business objectives is not part of business process quality management, and the quality of business objectives must be judged independently on the quality of their objectives. A similar question refers to whether business objectives are treated as an object or as a constraint of business process design. While this question has not been focussed directly by authors on business processes, we nevertheless can identify views on the issue that have evolved since the early days of business process reengineering.

During the early 1990s, authors such as Davenport and Short or Hammer and Champy advocated business process reengineering as a radical way of changing organisations. This involved reconsidering the objectives that were pursued by enacting business processes[7]. One demand made was that all processes (or, more precisely, process objectives) should be oriented towards "the customer" which reflects an user-based quality view (see Section 3.2). Of course, "customer" was a rather flexible notion as departments began to define other departments or management as their customer. However, it is clear that, at that time, assessing business processes involved assessing the business objectives that were pursued as well. If asked to ascertain the quality of a business process, we can assume that the advocates of reengineering would have commenced with scrutinising the associated business objective.

The reengineering approach, however, led to a number of issues that could not be easily resolved, such as change management and generally people-related topics [74]. One of these issues was that there was no clear way to support decisions on which processes serve the customer and which do not, which business objectives are important and which are not etc. Overall, it became apparent that radical approaches towards business process optimisation that did not focus on improving given processes but involved reconsidering whether process objectives made sense at all quickly led to a huge scope of change that overtaxed most if not all organisations. Consequently, the question which processes are actually required and, inherently, wich business objectives are to be pursued or if one business

[7] See, for instance, [18, p. 10]: "Process innovation [...] involves stepping back from a process to inquire into its overall business objective", or [19, p. 35]: "In doing reengineering, businesspeople must ask the most basic questions about their companies and how they operate: Why do we do what we do? And why do we do it the way we do?"

objective is to be preferred over another has been omitted from more recent approaches towards BPM. This trend even pertains to recent work by Hammer as one of the founders of the process reeingineering management philosophy, which can be observed in [75].

As a result, the mentioned decisions have been delegated to strategic management so that the business objectives associated with business processes are not the object of BPM anymore. This corresponds to the insight that business objectives are difficult to analytically assess with currently available methods, so it makes sense to treat them as part of a discipline not as analytically focused as BPM. For instance, Porter's influential article "What is Strategy?" refers to operational effectiveness as the ability to "get more out of their inputs than others because they eliminated wasted effort, employ more advanced technology, motivate employees better or have better insight into managing particular activities or sets of activities" [39]. A large part of these topics relates to BPM. Competitive strategy, however, is defined as "deliberately choosing a different set of activities to deliver a unique mix of value". Trade-offs between differing business objectives are thus seen as the subject of strategic management rather than BPM.

In summary, we conclude that our approach to exclude business objectives from the drivers of business process quality is broadly in line with current thinking on the scope of business process management as a whole.

A.3 Implications from Treating Business Objectives as Variables for Quality Assessment

Treating the definition of business objectives as a factor for the quality of the respective business process would lead to a quality standard comprising both optimum business objectives and minimum economic value consumption, instead of just minimum economic value consumption with achieving the business objective as a side condition. These alternative quality standards converge with two of the modes of the classic economic principle [76]: the minimum principle as minimising input for a given amount of output (corresponding to Definition 1) and the general optimum principle of reconciling input and output to the best economic advantage of the organisation [8].

Accordingly, the classic issue of the general optimum principle would also apply to a quality standard comprising business objectives as well as resources consumption. For primitive cases like maximising the amount of products manufactured while minimising material employed, it is clear that the general optimum principle cannot be pursued. When a more sophisticated phrasing like balancing input and output as to maximise economic value generation is chosen, this

[8] The maximum principle as maximising output for a given amount of input is also conceivable as a quality standard for business processes, but leads to similar issues as the general optimum principle.

general issue can be resolved, but two other obstacles remain: the requirement of valuating business process output, and the lack of comparability.

Evaluating the quality of business objectives in appropriate economic terms involves providing an economic evaluation of the business process output aspired as part of the business objective. Compared to evaluating resource consumption by business processes (see Section 5.2), this is far more complex. This can be illustrated by the example of an outgoing payments process. Business process input in this case consists of the checked invoices to be paid, the information system employed and labor. Even if additional assumptions for instance with respect to depreciation of the information system is required, we can assume that economic evaluation can be conducted at cost (see Section 5.2.3). On the output side, assessing the economic value of having executed payments would involve analysing what happens when each individual payment is not made in terms of economic cost – an area where we clearly leave sound analytic ground and enter into speculation.

Another issue arising with evaluating quality including business objectives refers to the lack of comparability. If we include the business objective in our quality standard, we not only need to establish whether economic value has been wasted on resources, but at the same time whether this value could have been put to better use or how much value could have been generated by any other process. In other words, this means that the system of comparable alternative processes that had been established via a common business objective disintegrates. The quality standard becomes undefinable because of its lack of boundaries, so quality assessment of a concrete process is not possible anymore.

Overall, we can conclude that optimum business objectives as part of the quality standard would certainly drive the level of complexity that needs to be resolved beyond practical limits, thereby compromising the measurability and transparency requirements.

A.4 Conclusion

As discussed in the previous paragraphs, the view that good business objectives constitute part of business process quality corresponds well to most views on quality, but not to the manufacturing-based view and the derived ISO quality definition. Also, scrutinising business objectives as part of BPM is not in line with current thinking on the scope of BPM. The decision which business objectives should be pursued is rather seen as a subject of business strategy or the definition of the organisation's business model. However, the biggest issue precluding variable business objectives in business process quality assessment are the implications with respect to practical applicability. We therefore omit optimum business objectives from our business process quality standard.

B The Credit Note Procedure Example

To illustrate the case for "radical" business process reengineering, Davenport and Short as well as Hammer and Champy in articles that were both published in summer 1990 described an example for process optimisation at Ford Motor Corporation [16,17]. The example relates to optimisation of the accounts payable process, one of the best-understood processes in terms of optimisation potentials in administrative functions.

The authors claim that Ford's North American operations were able to reduce capacity requirements in the accounts payable department by 75% by radically reengineering the process: instead of receiving and checking invoices, credit notes are issued to suppliers upon the receipt of goods. It is illustrative to take another look at the topic today.

Almost 20 years later, one would expect a practice that has been implemented with as much success at a well-known multinational company to have gained wide-spread acceptance. Personal observations during the last years, mainly when working with European manufacturing groups as a consultant, show that this is indeed the case and the practice is well-known and adopted in many companies. However, it is by no means pervasive. The practice is, for instance, very prevalent at automotive OEMs ("original equipment manufacturers", i.e. car makers), but not widely spread in the machine tools industry. Overall, it could be argued that as an estimate, on average less than 10% of total purchasing volume are processed via a credit note procedure.

This outcome can be ascribed to the fact that by applying credit note procedures instead of receiving invoices, work is not "obliterated" as claimed by Hammer, but merely shifted from the customer to the supplier: instead of the customer checking the invoice, the supplier checks the credit note. The new activities on the supplier side involve matching the original customer order against the delivery note and the credit note, which is rather similar to the original invoice checking process. This, of course, is only possible in industries where buyers are in a good bargaining position, hence the wide-spread adoption by automotive OEMs. As opposed to the claim of the advocates of business process reengineering, the workload has not been obliterated but merely reassigned. Moreover, the pressure to adopt a credit note procedure has lessened with the advent of advanced process automation techniques in the field, such as EDI and early scanning.

The example shows that even in prominent cases, the business process reengineering postulation of radically re-thinking whether activities or processes really need to be executed not always leads to tremendous results in the long run. Most reengineering successes that in reality led to more than incremental results were based on a combination of process reengineering, organisational reallocation of tasks and elimination of fringe activities.

Liste der bisher erschienenen Ulmer Informatik-Berichte

Einige davon sind per FTP von `ftp.informatik.uni-ulm.de` erhältlich
Die mit * markierten Berichte sind vergriffen

List of technical reports published by the University of Ulm

Some of them are available by FTP from `ftp.informatik.uni-ulm.de`
Reports marked with * are out of print

91-01 *Ker-I Ko, P. Orponen, U. Schöning, O. Watanabe*
Instance Complexity

91-02* *K. Gladitz, H. Fassbender, H. Vogler*
Compiler-Based Implementation of Syntax-Directed Functional Programming

91-03* *Alfons Geser*
Relative Termination

91-04* *J. Köbler, U. Schöning, J. Toran*
Graph Isomorphism is low for PP

91-05 *Johannes Köbler, Thomas Thierauf*
Complexity Restricted Advice Functions

91-06* *Uwe Schöning*
Recent Highlights in Structural Complexity Theory

91-07* *F. Green, J. Köbler, J. Toran*
The Power of Middle Bit

91-08* *V.Arvind, Y. Han, L. Hamachandra, J. Köbler, A. Lozano, M. Mundhenk, A. Ogiwara, U. Schöning, R. Silvestri, T. Thierauf*
Reductions for Sets of Low Information Content

92-01* *Vikraman Arvind, Johannes Köbler, Martin Mundhenk*
On Bounded Truth-Table and Conjunctive Reductions to Sparse and Tally Sets

92-02* *Thomas Noll, Heiko Vogler*
Top-down Parsing with Simulataneous Evaluation of Noncircular Attribute Grammars

92-03 *Fakultät für Informatik*
17. Workshop über Komplexitätstheorie, effiziente Algorithmen und Datenstrukturen

92-04* *V. Arvind, J. Köbler, M. Mundhenk*
Lowness and the Complexity of Sparse and Tally Descriptions

92-05* *Johannes Köbler*
Locating P/poly Optimally in the Extended Low Hierarchy

92-06* *Armin Kühnemann, Heiko Vogler*
Synthesized and inherited functions -a new computational model for syntax-directed semantics

92-07* *Heinz Fassbender, Heiko Vogler*
A Universal Unification Algorithm Based on Unification-Driven Leftmost Outermost Narrowing

92-08* *Uwe Schöning*
On Random Reductions from Sparse Sets to Tally Sets

92-09* *Hermann von Hasseln, Laura Martignon*
Consistency in Stochastic Network

92-10 *Michael Schmitt*
A Slightly Improved Upper Bound on the Size of Weights Sufficient to Represent Any Linearly Separable Boolean Function

92-11 *Johannes Köbler, Seinosuke Toda*
On the Power of Generalized MOD-Classes

92-12 *V. Arvind, J. Köbler, M. Mundhenk*
Reliable Reductions, High Sets and Low Sets

92-13 *Alfons Geser*
On a monotonic semantic path ordering

92-14* *Joost Engelfriet, Heiko Vogler*
The Translation Power of Top-Down Tree-To-Graph Transducers

93-01 *Alfred Lupper, Konrad Froitzheim*
AppleTalk Link Access Protocol basierend auf dem Abstract Personal Communications Manager

93-02 *M.H. Scholl, C. Laasch, C. Rich, H.-J. Schek, M. Tresch*
The COCOON Object Model

93-03 *Thomas Thierauf, Seinosuke Toda, Osamu Watanabe*
On Sets Bounded Truth-Table Reducible to P-selective Sets

93-04 *Jin-Yi Cai, Frederic Green, Thomas Thierauf*
On the Correlation of Symmetric Functions

93-05 *K.Kuhn, M.Reichert, M. Nathe, T. Beuter, C. Heinlein, P. Dadam*
A Conceptual Approach to an Open Hospital Information System

93-06 *Klaus Gaßner*
Rechnerunterstützung für die konzeptuelle Modellierung

93-07 *Ullrich Keßler, Peter Dadam*
Towards Customizable, Flexible Storage Structures for Complex Objects

94-01 *Michael Schmitt*
On the Complexity of Consistency Problems for Neurons with Binary Weights

94-02 *Armin Kühnemann, Heiko Vogler*
A Pumping Lemma for Output Languages of Attributed Tree Transducers

94-03 *Harry Buhrman, Jim Kadin, Thomas Thierauf*
On Functions Computable with Nonadaptive Queries to NP

94-04 *Heinz Faßbender, Heiko Vogler, Andrea Wedel*
Implementation of a Deterministic Partial E-Unification Algorithm for Macro Tree Transducers

94-05 *V. Arvind, J. Köbler, R. Schuler*
On Helping and Interactive Proof Systems

94-06 *Christian Kalus, Peter Dadam*
Incorporating record subtyping into a relational data model

94-07 *Markus Tresch, Marc H. Scholl*
A Classification of Multi-Database Languages

94-08 *Friedrich von Henke, Harald Rueß*
Arbeitstreffen Typtheorie: Zusammenfassung der Beiträge

94-09 *F.W. von Henke, A. Dold, H. Rueß, D. Schwier, M. Strecker*
Construction and Deduction Methods for the Formal Development of Software

94-10 *Axel Dold*
Formalisierung schematischer Algorithmen

94-11 *Johannes Köbler, Osamu Watanabe*
New Collapse Consequences of NP Having Small Circuits

94-12 *Rainer Schuler*
On Average Polynomial Time

94-13 *Rainer Schuler, Osamu Watanabe*
Towards Average-Case Complexity Analysis of NP Optimization Problems

94-14 *Wolfram Schulte, Ton Vullinghs*
Linking Reactive Software to the X-Window System

94-15 *Alfred Lupper*
Namensverwaltung und Adressierung in Distributed Shared Memory-Systemen

94-16 *Robert Regn*
Verteilte Unix-Betriebssysteme

94-17 *Helmuth Partsch*
Again on Recognition and Parsing of Context-Free Grammars:
Two Exercises in Transformational Programming

94-18 *Helmuth Partsch*
Transformational Development of Data-Parallel Algorithms: an Example

95-01 *Oleg Verbitsky*
On the Largest Common Subgraph Problem

95-02 *Uwe Schöning*
Complexity of Presburger Arithmetic with Fixed Quantifier Dimension

95-03 *Harry Buhrman,Thomas Thierauf*
The Complexity of Generating and Checking Proofs of Membership

95-04 *Rainer Schuler, Tomoyuki Yamakami*
Structural Average Case Complexity

95-05 *Klaus Achatz, Wolfram Schulte*
Architecture Indepentent Massive Parallelization of Divide-And-Conquer Algorithms

95-06 *Christoph Karg, Rainer Schuler*
Structure in Average Case Complexity

95-07 *P. Dadam, K. Kuhn, M. Reichert, T. Beuter, M. Nathe*
ADEPT: Ein integrierender Ansatz zur Entwicklung flexibler, zuverlässiger kooperierender Assistenzsysteme in klinischen Anwendungsumgebungen

95-08 *Jürgen Kehrer, Peter Schulthess*
Aufbereitung von gescannten Röntgenbildern zur filmlosen Diagnostik

95-09 *Hans-Jörg Burtschick, Wolfgang Lindner*
On Sets Turing Reducible to P-Selective Sets

95-10 *Boris Hartmann*
Berücksichtigung lokaler Randbedingung bei globaler Zieloptimierung mit neuronalen Netzen am Beispiel Truck Backer-Upper

95-12 *Klaus Achatz, Wolfram Schulte*
Massive Parallelization of Divide-and-Conquer Algorithms over Powerlists

95-13 *Andrea Mößle, Heiko Vogler*
Efficient Call-by-value Evaluation Strategy of Primitive Recursive Program Schemes

95-14 *Axel Dold, Friedrich W. von Henke, Holger Pfeifer, Harald Rueß*
A Generic Specification for Verifying Peephole Optimizations

96-01 *Ercüment Canver, Jan-Tecker Gayen, Adam Moik*
Formale Entwicklung der Steuerungssoftware für eine elektrisch ortsbediente Weiche mit VSE

96-02 *Bernhard Nebel*
Solving Hard Qualitative Temporal Reasoning Problems: Evaluating the Efficiency of Using the ORD-Horn Class

96-03 *Ton Vullinghs, Wolfram Schulte, Thilo Schwinn*
An Introduction to TkGofer

96-04 *Thomas Beuter, Peter Dadam*
Anwendungsspezifische Anforderungen an Workflow-Mangement-Systeme am Beispiel der Domäne Concurrent-Engineering

96-05 *Gerhard Schellhorn, Wolfgang Ahrendt*
Verification of a Prolog Compiler - First Steps with KIV

96-06 *Manindra Agrawal, Thomas Thierauf*
Satisfiability Problems

96-07 *Vikraman Arvind, Jacobo Torán*
A nonadaptive NC Checker for Permutation Group Intersection

96-08 *David Cyrluk, Oliver Möller, Harald Rueß*
An Efficient Decision Procedure for a Theory of Fix-Sized Bitvectors with Composition and Extraction

96-09 *Bernd Biechele, Dietmar Ernst, Frank Houdek, Joachim Schmid, Wolfram Schulte*
Erfahrungen bei der Modellierung eingebetteter Systeme mit verschiedenen SA/RT–Ansätzen

96-10 *Falk Bartels, Axel Dold, Friedrich W. von Henke, Holger Pfeifer, Harald Rueß*
Formalizing Fixed-Point Theory in PVS

96-11 *Axel Dold, Friedrich W. von Henke, Holger Pfeifer, Harald Rueß*
Mechanized Semantics of Simple Imperative Programming Constructs

96-12 *Axel Dold, Friedrich W. von Henke, Holger Pfeifer, Harald Rueß*
Generic Compilation Schemes for Simple Programming Constructs

96-13 *Klaus Achatz, Helmuth Partsch*
From Descriptive Specifications to Operational ones: A Powerful Transformation Rule, its Applications and Variants

97-01 *Jochen Messner*
Pattern Matching in Trace Monoids

97-02 *Wolfgang Lindner, Rainer Schuler*
A Small Span Theorem within P

97-03 *Thomas Bauer, Peter Dadam*
A Distributed Execution Environment for Large-Scale Workflow Management Systems with Subnets and Server Migration

97-04 *Christian Heinlein, Peter Dadam*
Interaction Expressions - A Powerful Formalism for Describing Inter-Workflow Dependencies

97-05 *Vikraman Arvind, Johannes Köbler*
On Pseudorandomness and Resource-Bounded Measure

97-06 *Gerhard Partsch*
Punkt-zu-Punkt- und Mehrpunkt-basierende LAN-Integrationsstrategien für den digitalen Mobilfunkstandard DECT

97-07 *Manfred Reichert, Peter Dadam*
$ADEPT_{flex}$ - Supporting Dynamic Changes of Workflows Without Loosing Control

97-08 *Hans Braxmeier, Dietmar Ernst, Andrea Mößle, Heiko Vogler*
The Project NoName - A functional programming language with its development environment

97-09 *Christian Heinlein*
Grundlagen von Interaktionsausdrücken

97-10 *Christian Heinlein*
Graphische Repräsentation von Interaktionsausdrücken

97-11 *Christian Heinlein*
Sprachtheoretische Semantik von Interaktionsausdrücken

97-12 *Gerhard Schellhorn, Wolfgang Reif*
Proving Properties of Finite Enumerations: A Problem Set for Automated Theorem Provers

97-13 *Dietmar Ernst, Frank Houdek, Wolfram Schulte, Thilo Schwinn*
Experimenteller Vergleich statischer und dynamischer Softwareprüfung für eingebettete Systeme

97-14 *Wolfgang Reif, Gerhard Schellhorn*
Theorem Proving in Large Theories

97-15 *Thomas Wennekers*
Asymptotik rekurrenter neuronaler Netze mit zufälligen Kopplungen

97-16 *Peter Dadam, Klaus Kuhn, Manfred Reichert*
Clinical Workflows - The Killer Application for Process-oriented Information Systems?

97-17 *Mohammad Ali Livani, Jörg Kaiser*
EDF Consensus on CAN Bus Access in Dynamic Real-Time Applications

97-18 *Johannes Köbler,Rainer Schuler*
Using Efficient Average-Case Algorithms to Collapse Worst-Case Complexity Classes

98-01 *Daniela Damm, Lutz Claes, Friedrich W. von Henke, Alexander Seitz, Adelinde Uhrmacher, Steffen Wolf*
Ein fallbasiertes System für die Interpretation von Literatur zur Knochenheilung

98-02 *Thomas Bauer, Peter Dadam*
Architekturen für skalierbare Workflow-Management-Systeme - Klassifikation und Analyse

98-03 *Marko Luther, Martin Strecker*
A guided tour through *Typelab*

98-04 *Heiko Neumann, Luiz Pessoa*
Visual Filling-in and Surface Property Reconstruction

98-05 *Ercüment Canver*
Formal Verification of a Coordinated Atomic Action Based Design

98-06 *Andreas Küchler*
On the Correspondence between Neural Folding Architectures and Tree Automata

98-07 *Heiko Neumann, Thorsten Hansen, Luiz Pessoa*
Interaction of ON and OFF Pathways for Visual Contrast Measurement

98-08 *Thomas Wennekers*
Synfire Graphs: From Spike Patterns to Automata of Spiking Neurons

98-09 *Thomas Bauer, Peter Dadam*
Variable Migration von Workflows in *ADEPT*

98-10 *Heiko Neumann, Wolfgang Sepp*
Recurrent V1 – V2 Interaction in Early Visual Boundary Processing

98-11 *Frank Houdek, Dietmar Ernst, Thilo Schwinn*
Prüfen von C–Code und Statmate/Matlab–Spezifikationen: Ein Experiment

98-12 *Gerhard Schellhorn*
Proving Properties of Directed Graphs: A Problem Set for Automated Theorem Provers

98-13 *Gerhard Schellhorn, Wolfgang Reif*
Theorems from Compiler Verification: A Problem Set for Automated Theorem Provers

98-14 *Mohammad Ali Livani*
SHARE: A Transparent Mechanism for Reliable Broadcast Delivery in CAN

98-15 *Mohammad Ali Livani, Jörg Kaiser*
Predictable Atomic Multicast in the Controller Area Network (CAN)

99-01 *Susanne Boll, Wolfgang Klas, Utz Westermann*
A Comparison of Multimedia Document Models Concerning Advanced Requirements

99-02 *Thomas Bauer, Peter Dadam*
Verteilungsmodelle für Workflow-Management-Systeme - Klassifikation und Simulation

99-03 *Uwe Schöning*
On the Complexity of Constraint Satisfaction

99-04 *Ercument Canver*
Model-Checking zur Analyse von Message Sequence Charts über Statecharts

99-05 *Johannes Köbler, Wolfgang Lindner, Rainer Schuler*
Derandomizing RP if Boolean Circuits are not Learnable

99-06 *Utz Westermann, Wolfgang Klas*
Architecture of a DataBlade Module for the Integrated Management of Multimedia Assets

99-07 *Peter Dadam, Manfred Reichert*
Enterprise-wide and Cross-enterprise Workflow Management: Concepts, Systems, Applications. Paderborn, Germany, October 6, 1999, GI–Workshop Proceedings, Informatik '99

99-08 *Vikraman Arvind, Johannes Köbler*
Graph Isomorphism is Low for ZPP^{NP} and other Lowness results

99-09 *Thomas Bauer, Peter Dadam*
Efficient Distributed Workflow Management Based on Variable Server Assignments

2000-02 *Thomas Bauer, Peter Dadam*
Variable Serverzuordnungen und komplexe Bearbeiterzuordnungen im Workflow-Management-System ADEPT

2000-03 *Gregory Baratoff, Christian Toepfer, Heiko Neumann*
Combined space-variant maps for optical flow based navigation

2000-04 *Wolfgang Gehring*
Ein Rahmenwerk zur Einführung von Leistungspunktsystemen

2000-05 *Susanne Boll, Christian Heinlein, Wolfgang Klas, Jochen Wandel*
Intelligent Prefetching and Buffering for Interactive Streaming of MPEG Videos

2000-06 *Wolfgang Reif, Gerhard Schellhorn, Andreas Thums*
Fehlersuche in Formalen Spezifikationen

2000-07 *Gerhard Schellhorn, Wolfgang Reif (eds.)*
FM-Tools 2000: The 4th Workshop on Tools for System Design and Verification

2000-08 *Thomas Bauer, Manfred Reichert, Peter Dadam*
Effiziente Durchführung von Prozessmigrationen in verteilten Workflow-Management-Systemen

2000-09 *Thomas Bauer, Peter Dadam*
Vermeidung von Überlastsituationen durch Replikation von Workflow-Servern in ADEPT

2000-10 *Thomas Bauer, Manfred Reichert, Peter Dadam*
Adaptives und verteiltes Workflow-Management

2000-11 *Christian Heinlein*
Workflow and Process Synchronization with Interaction Expressions and Graphs

2001-01 *Hubert Hug, Rainer Schuler*
DNA-based parallel computation of simple arithmetic

2001-02 *Friedhelm Schwenker, Hans A. Kestler, Günther Palm*
3-D Visual Object Classification with Hierarchical Radial Basis Function Networks

2001-03 *Hans A. Kestler, Friedhelm Schwenker, Günther Palm*
RBF network classification of ECGs as a potential marker for sudden cardiac death

2001-04 *Christian Dietrich, Friedhelm Schwenker, Klaus Riede, Günther Palm*
Classification of Bioacoustic Time Series Utilizing Pulse Detection, Time and Frequency Features and Data Fusion

2002-01 *Stefanie Rinderle, Manfred Reichert, Peter Dadam*
Effiziente Verträglichkeitsprüfung und automatische Migration von Workflow-Instanzen bei der Evolution von Workflow-Schemata

2002-02 *Walter Guttmann*
Deriving an Applicative Heapsort Algorithm

2002-03 *Axel Dold, Friedrich W. von Henke, Vincent Vialard, Wolfgang Goerigk*
A Mechanically Verified Compiling Specification for a Realistic Compiler

2003-01 *Manfred Reichert, Stefanie Rinderle, Peter Dadam*
A Formal Framework for Workflow Type and Instance Changes Under Correctness Checks

2003-02 *Stefanie Rinderle, Manfred Reichert, Peter Dadam*
Supporting Workflow Schema Evolution By Efficient Compliance Checks

2003-03 *Christian Heinlein*
Safely Extending Procedure Types to Allow Nested Procedures as Values

2003-04 *Stefanie Rinderle, Manfred Reichert, Peter Dadam*
On Dealing With Semantically Conflicting Business Process Changes.

2003-05 *Christian Heinlein*
Dynamic Class Methods in Java

2003-06 *Christian Heinlein*
Vertical, Horizontal, and Behavioural Extensibility of Software Systems

2003-07 *Christian Heinlein*
Safely Extending Procedure Types to Allow Nested Procedures as Values (Corrected Version)

2003-08 *Changling Liu, Jörg Kaiser*
Survey of Mobile Ad Hoc Network Routing Protocols)

2004-01 *Thom Frühwirth, Marc Meister (eds.)*
First Workshop on Constraint Handling Rules

2004-02 *Christian Heinlein*
Concept and Implementation of C+++, an Extension of C++ to Support User-Defined Operator Symbols and Control Structures

2004-03 *Susanne Biundo, Thom Frühwirth, Günther Palm(eds.)*
Poster Proceedings of the 27th Annual German Conference on Artificial Intelligence

2005-01 *Armin Wolf, Thom Frühwirth, Marc Meister (eds.)*
19th Workshop on (Constraint) Logic Programming

2005-02 *Wolfgang Lindner (Hg.), Universität Ulm , Christopher Wolf (Hg.) KU Leuven*
2. Krypto-Tag – Workshop über Kryptographie, Universität Ulm

2005-03 *Walter Guttmann, Markus Maucher*
Constrained Ordering

2006-01 *Stefan Sarstedt*
Model-Driven Development with ACTIVECHARTS, Tutorial

2006-02 *Alexander Raschke, Ramin Tavakoli Kolagari*
Ein experimenteller Vergleich zwischen einer plan-getriebenen und einer leichtgewichtigen Entwicklungsmethode zur Spezifikation von eingebetteten Systemen

2006-03 *Jens Kohlmeyer, Alexander Raschke, Ramin Tavakoli Kolagari*
Eine qualitative Untersuchung zur Produktlinien-Integration über Organisationsgrenzen hinweg

2006-04 *Thorsten Liebig*
Reasoning with OWL - System Support and Insights –

2008-01 *H.A. Kestler, J. Messner, A. Müller, R. Schuler*
On the complexity of intersecting multiple circles for graphical display

2008-02	*Manfred Reichert, Peter Dadam, Martin Jurisch,l Ulrich Kreher, Kevin Göser, Markus Lauer* Architectural Design of Flexible Process Management Technology
2008-03	*Frank Raiser* Semi-Automatic Generation of CHR Solvers from Global Constraint Automata
2008-04	*Ramin Tavakoli Kolagari, Alexander Raschke, Matthias Schneiderhan, Ian Alexander* Entscheidungsdokumentation bei der Entwicklung innovativer Systeme für produktlinien-basierte Entwicklungsprozesse
2008-05	*Markus Kalb, Claudia Dittrich, Peter Dadam* Support of Relationships Among Moving Objects on Networks
2008-06	*Matthias Frank, Frank Kargl, Burkhard Stiller (Hg.)* WMAN 2008 – KuVS Fachgespräch über Mobile Ad-hoc Netzwerke
2008-07	*M. Maucher, U. Schöning, H.A. Kestler* An empirical assessment of local and population based search methods with different degrees of pseudorandomness
2008-08	*Henning Wunderlich* Covers have structure
2008-09	*Karl-Heinz Niggl, Henning Wunderlich* Implicit characterization of FPTIME and NC revisited
2008-10	*Henning Wunderlich* On span-P^{cc} and related classes in structural communication complexity
2008-11	*M. Maucher, U. Schöning, H.A. Kestler* On the different notions of pseudorandomness
2008-12	*Henning Wunderlich* On Toda's Theorem in structural communication complexity
2008-13	*Manfred Reichert, Peter Dadam* Realizing Adaptive Process-aware Information Systems with ADEPT2
2009-01	*Peter Dadam, Manfred Reichert* The ADEPT Project: A Decade of Research and Development for Robust and Fexible Process Support Challenges and Achievements
2009-02	*Peter Dadam, Manfred Reichert, Stefanie Rinderle-Ma, Kevin Göser, Ulrich Kreher, Martin Jurisch* Von ADEPT zur AristaFlow® BPM Suite – Eine Vision wird Realität "Correctness by Construction" und flexible, robuste Ausführung von Unternehmensprozessen

2009-03	*Alena Hallerbach, Thomas Bauer, Manfred Reichert* Correct Configuration of Process Variants in Provop
2009-04	*Martin Bader* On Reversal and Transposition Medians
2009-05	*Barbara Weber, Andreas Lanz, Manfred Reichert* Time Patterns for Process-aware Information Systems: A Pattern-based Analysis
2009-06	*Stefanie Rinderle-Ma, Manfred Reichert* Adjustment Strategies for Non-Compliant Process Instances
2009-07	*H.A. Kestler, B. Lausen, H. Binder H.-P. Klenk. F. Leisch, M. Schmid* Statistical Computing 2009 – Abstracts der 41. Arbeitstagung
2009-08	*Ulrich Kreher, Manfred Reichert, Stefanie Rinderle-Ma, Peter Dadam* Effiziente Repräsentation von Vorlagen- und Instanzdaten in Prozess-Management-Systemen
2009-09	*Dammertz, Holger, Alexander Keller, Hendrik P.A. Lensch* Progressive Point-Light-Based Global Illumination
2009-10	*Dao Zhou, Christoph Müssel, Ludwig Lausser, Martin Hopfensitz, Michael Kühl, Hans A. Kestler* Boolean networks for modeling and analysis of gene regulation
2009-11	*J. Hanika, H.P.A. Lensch, A. Keller* Two-Level Ray Tracing with Recordering for Highly Complex Scenes
2009-12	*Stephan Buchwald, Thomas Bauer, Manfred Reichert* Durchgängige Modellierung von Geschäftsprozessen durch Einführung eines Abbildungsmodells: Ansätze, Konzepte, Notationen
2010-01	*Hariolf Beth, Frank Raiser, Thom Frühwirth* A Complete and Terminating Execution Model for Constraint Handling Rules
2010-02	*Ulrich Kreher, Manfred Reichert* Speichereffiziente Repräsentation instanzspezifischer Änderungen in Prozess-Management-Systemen
2010-03	*Patrick Frey* Case Study: Engine Control Application
2010-04	*Matthias Lohrmann und Manfred Reichert* Basic Considerations on Business Process Quality
2010-05	*HA Kestler, H Binder, B Lausen, H-P Klenk, M Schmid, F Leisch (eds):* Statistical Computing 2010 - Abstracts der 42. Arbeitstagung

Ulmer Informatik-Berichte
ISSN 0939-5091

Herausgeber:
Universität Ulm
Fakultät für Ingenieurwissenschaften und Informatik
89069 Ulm