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Evaluating Quality of Business Processes

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Abstract. One of the key activities in developing information systems is that of modeling the constituent parts of both existing and future business processes so that the resultant system is aligned to the business. This duality of scope often referred to as co-development, provides the basis for aligning technical systems to business processes and business goals and has a profound effect on the effectiveness of the delivered system. Through conceptual modeling, analysis and evaluation, Requirements Engineering offers opportunities to facilitate co-development activities. In this paper we focus on evaluating the quality of business processes through their conceptual models, at the requirements phase. We adopt an intentional approach to defining quality requirements and we focus on the way that these requirements impact on business processes. We present an approach for defining, elaborating and evaluating quality factors that can be measured and reflected upon against stated business goals.

Keywords: Quality; Non-Functional Requirements; Business Process; Business Process Modeling.

"Quality requirements, are useful only when they are represented quantitatively so that they can be measured."

Martin Glinz

1 Introduction

Today, new business forces are demanding enterprises to adopt appropriate techniques for understanding the behavior of the business system and its influence on the development of information systems that support its operation. Rapid organizational change, knowledge-intensity of goods and services, the growth in organizational scope, and information technology has intensified organizational needs for such techniques. While information systems continue to serve traditional business needs such as co-ordination of production and enhancements of services offered, a new and important role has emerged namely the potential of such systems in adopting a more supervisory and strategic support role to the extent that their deployment could be used for transforming enterprises and even industries. The consequence of these
developments is the need for aligning information systems development to business system development. Co-development is the term often used for this type of alignment [1].

Successful co-development requires attention by system developers at an early development phase and Requirements Engineering (RE) in particular offers opportunities for the modeling, analysis and evaluation of alternative futures [2]. To this end, business process modeling (BPM) has become, for some considerable time, an important part of work practices, culminating in standards such as the Business Process Modeling Notation (BPMN) [3] but also in fruitful research endeavors involving the evolution from information modeling to enterprise modeling [4] in schemes for the modeling of business goals [5, 6], business objects [7], and business rules [8].

There is a commonly agreed set of features pertaining to business processes [9-14]. In summary a business process demonstrates the following characteristics:

- A business process has well identified products and customers;
- A business process has goals, i.e., it is intended to achieve defined business objectives aiming to create value to customers;
- A business process involves several activities which collectively achieve defined business process goals and create value to customers;
- A business process crosses functional/organizational boundaries; it concerns the collaboration between organizational actors that are contributing to (or constraining) the satisfying of business objectives.

Given these characteristics there are two observations to be made.

First, business processes involve many different stakeholders. People are heavily dominated by the systems around them and any change to the business processes will inevitably involve such system stakeholders in considering the effect that new designs will have on work practices, on the added value offered by new processes, on the cost involved in running the business with the new processes and more generally on how well the new processes meet their state quality objectives [15]. Approaches used to address stakeholder collaboration include collaborative requirements management cf. [16], scenarios cf. [17], visualization cf. [18], use of domain knowledge cf. [19], use of indicators cf. [20] and model transformation cf. [21].

Second, business processes exhibit complex dynamic behavior. This complexity is not so much a result of voluminous components (although this could indeed be true in some cases) but, rather because of the interrelationships between system components that may involve a great deal of diversity from operational, to strategic, to legislative and financial factors. Even in systems with a relatively small number of parts, changes that involve the simultaneous change of many variables, some of which may be distant in space and time, can be difficult or impossible to understand without appropriate support mechanisms. One is interested therefore on understanding this rate of change, so that one can make predictions about alternative implementations. Approaches used to address the problem of causality in complex dynamic businesses
include systems thinking cf. [22], modeling of system behaviors cf. [23], architecture-driven prioritization cf. [24], and simulation cf. [25].

Our focus in this paper is on quality of business processes. We adopt a quantitative approach that attempts to address both of the above two issues through a framework that considers BPM coupled to quality factors that can be subjected to evaluation. In this way, stakeholders are involved at different levels of concern, from strategic (e.g. ‘what business quality goals are fulfilled?’) to operational (e.g. ‘what changes are required at the physical level to meet an acceptable level of service satisfying the quality goals?’) and also, the designing of business processes can be guided by an experimental paradigm that considers the partial or total business process quality performance (e.g. ‘how should a business process be designed to ensure that there is no shortage of materials?’).

The proposed approach is grounded on three objectives:

i. To use conceptual models of BPM as the basis of the evaluation. These models obviously would represent abstractions of the real business processes. Our concern is not on the evaluation of the models themselves (as has been the case in other lines of research work in this area) but rather we assume that the models are well formed and we focus on those details that reflect key concepts of a business process; for example, for the concept of ‘activity’ we may be interested in evaluating ‘cycle time’ as an element of ‘performance’. The model becomes the medium of analysis but the values for cycle time would be real values measured on the actual business activity.

ii. To make use of conceptual models that conform to a unified meta-model. Since the models are to be shared by all stakeholders, they should be expressed in such a way so as to be amenable to inspection and critique and revision. However this can often be compromised due the variation in the conceptual modelling languages used. There are practical situations where a common approach is not feasible; for example consider the case of inter-enterprise integration efforts, where different approaches, and cultures may prevail. We argue therefore, that there is a need to view these structures through a lens that focuses on the semantics of the application rather than the syntax of the technique used to describe the application. We address this need through a meta-model that unifies the semantics of the most widely adopted contemporary business process modelling approaches.

iii. To evaluate processes on the basis of quality factors defined on key business process concepts of the unified meta-model. These factors and corresponding metrics provide stakeholders with the ability to test how well business processes perform against quality objectives.

The paper is organized as follows. Section 2 presents a brief analysis of related areas in order to examine the degree to which quality of a business process and its concepts have been considered. In Section 3, a methodological framework is introduced that provides an overall specification of the proposed approach. This framework defines the main conceptual constructs and their interrelationships that collectively form the building blocks of a quality-oriented evaluation approach. Section 4, a business process meta-model is presented as a unified view of different BPM techniques.
purpose of this is to have a language-independent view upon which quality factors can be established. Section 5 focuses on realization of quality dimensions and factors as well as metrics of business process concepts and presents the quality meta-model. The paper concludes in Section 6 with a number of observations, reflections and suggestions for future work while highlighting limitations of the current work.

2 Dealing with Business Process Quality Evaluation

Different authors deal with the concept of quality in different ways and within different fields such as in Business Organization c.f. [26], Management c.f. [27], Software Engineering c.f. [28] and Requirements Engineering c.f. [29]. An attempt is made in [30] to navigate through the maze of many definitions on quality (primarily in the area of requirements but not exclusively) with the conclusion that the many different classification schemes are inconsistent terminologically as well as categorically. What is agreed however by most of the works investigated is that the concept of quality, irrespective of the way that different approaches handle it, is that it plays a key role in the acceptance of any software-based system.

In this paper we focus on quality at the business process level using a well-formed BPM as the context of evaluation for the different facets of a business process. Quality of business processes has been investigated in a variety of ways. Synoptically, the following introduces some of the most relevant approaches within the areas of business process management and RE. Heravizadeh et al pay attention to the capturing of quality dimensions of business processes [31]. Heinrich et al collect quality characteristics and attributes of processes and BPM languages are enhanced in order to express these attributes [32]. They adopt the ISO/IEC9126 standard (quality of software) for evaluating business processes. Concepts such as activities, actors, information and physical objects as well as required resources are considered by Heinrich et al for evaluation [33]. Pavolovski [34] proposes two new artifacts to model the constraints associated with a business process. Pourshahid et al introduce a framework for measuring and aligning processes with goals [35]. The focus is on business process as a whole rather than its constituent parts. Saeedi et al put forward an approach for incorporating a set of quality requirements into BPMN [36]. Donzelli and Bresciani [37] propose an approach in which quality modeling extends the utility of goal-oriented, agent-based RE techniques, enabling the resolution of organizational and soft systems issues. Al-Balushi et al [38] focus on the identification of conflicts in quality definitions using an analysis tool supported by domain ontology.
The approach introduced in this paper in some ways complements and in others extends existing approaches by putting emphasis on defining those factors that can be used to measure quality of different constructs of a business process and by formally defining metrics for their evaluation.

3 Methodological Framework

Methodologically, our approach is intention-driven and more specifically motivated by the well-known and widely used Goal-Question-Metric approach (GQM). We aim to link high-level business goals to detailed, objective and quantifiable components of business processes. There are three goal-oriented concepts that are found in GQM namely those of “Quality Goal”, “Quality Question” and “Quality Factor”. In our approach these are complemented by a set of concepts that link requirements to specific facets of business processes, their quality factors and corresponding metrics.

The meta-model of Fig. 1 represents a partial, high-level view of the entire meta-model of our approach, the purpose of which in this paper to identify those elements that play a key role in the way that the approach may be utilized.

![Fig. 1 Methodological Approach](image)

A Quality Goal is an abstract requirement and documented by the Stakeholder interested in achieving this goal [39]. It can be said that, for evaluating quality of a Business Process, Quality Goals should be taken into account as expressions of Quality Requirements. Conversely, business
architecture and in particular Business Process are strongly influenced by the Quality Goals an organization is striving for [40].

This leads us to the specification of Quality Factors and Quality Metrics associated with the desired Quality Goals. A Quality Goal is operationally defined by a set of Questions to which Quality Factor values are provided as possible answers [39]. Similar to [41], Quality Factors are grouped into Quality Dimensions, each Dimension representing a facet of business process quality. A Quality Factor represents a particular aspect of a given Dimension. A Quality Factor is associated with a set of Quality Metrics concerned with its evaluation. In practice, several Quality Metrics can be associated for the same Quality Factor as there might be several ways for evaluating it. Different stakeholders can introduce different sets of metrics based on their needs [42].

The association of Quality Requirements to a Business Process can be established if the business process is properly modeled whereby the target of the requirement will be part (occasionally the whole) of the process, e.g. concepts such as activity. Business Process Modeling Techniques provide standard ways for presenting and communicating Business Processes in terms of Business Process Models.

The plethora of different BPM techniques however, presents a dilemma regarding the utility of the quality framework. Should the framework be dedicated to a single, perhaps popular modeling technique or should it be abstract enough to be used universally. Although, there are trends pointing towards some form of standardization, it could be argued that there is still a long way before reaching the state of a standard Business Process Modeling Technique. In the absence of a universally accepted, and more importantly single technique used in practice, we argue that it is more useful if the quality framework can be used in the context of a unified and technique-independent Business Process Meta-Model. There are many situations where it is more appropriate to allow the multiplicity of the use of these techniques by multiple business process analysts. Therefore, our proposal aims to avoid being tied to a specific language or notation. This is achieved by focusing on the semantic level via developing a Business Process Meta-model. Such meta-model can be developed by integrating Business Process Concepts of different Business Process Modeling Techniques into a unified model, a matter that is discussed further in the next section.

4 The Unified Business Process Meta-model

A model is an abstract representation of an original (like a system or a problem domain) for a given purpose [43]. The process of modeling is arguably the most widely used technique within design activities, including Requirements Engineering,
Software Engineering, Databases and business process engineering. There are currently many BPM methods and techniques being advocated or practiced. On closer inspection however, at a semantic level, there are many similarities and a great deal of convergence. Yet the plethora of these modeling approaches persists. In practice to a large extent, this is due to investment in resources in adopting a particular method, training developers, developing applications etc., all of which mitigate towards a continuation of the status quo. Furthermore, there are increasingly many situations (distributed projects, outsourced projects, integrated projects) where a single modeling approach is neither practical nor feasible. It is therefore important to recognize that this multiplicity of BPM approaches is likely to persist in practice. From a theoretical perspective however, it is vital that there is a clear understanding of the underlying semantics of these approaches, their overlaps, differences and similarities. Only then will it be possible to evaluate alternative approaches, or to engage them in a collaborative manner.

There is a need for a systematic representation of concepts and relationships between the concepts of different BPM techniques in the form of a unified and integrating conceptual model. We propose a business process meta-model resulting from the integration of different BPM techniques’ concepts into a single and unified framework (Fig 2). From a practical perspective, the meta-model has been shown to be valid for the following approaches: Business Process Modeling Notation (BPMN); Integrated Definition for Function Modeling (IDEF0-IDEF3); Role Activity Diagram (RAD); Unified Modeling Language Activity Diagram (UML-AD); (Structured Analysis and Design Technique (SADT); Event-driven Process Chain (EPC).

Fig. 2. A general (partial) view of the unified business process meta-model

For a more complete view of the unified model, the interested reader can refer to [44]. In this paper, we provide a synoptic view of the meta-model. One can view the unified meta-model in terms of 4 perspectives:

- Functional: What is going to be performed? (e.g. Activity)
• Behavioral: How it is performed? (e.g. Sequence flow)
• Organizational: Who does it? (e.g. Swimlane)
• Informational: (what is produced/ exchanged? (e.g. Output)

5 Quality Factors, Metrics and the Quality Meta-model

The following quality dimensions are considered: performance, efficiency, reliability, recoverability, permissibility, and availability. A quality factor represents a particular aspect of a given dimension. Table 1 presents, in a summary form, the 6 quality dimensions and their corresponding quality factors. Each factor is associated with one or more concepts found in the unified business process model.

<table>
<thead>
<tr>
<th>Business Process Concept</th>
<th>Dimension</th>
<th>Factor</th>
<th>Event</th>
<th>Output</th>
<th>Input</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>Throughput</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td></td>
<td>Cycle Time</td>
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<td></td>
<td>X</td>
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<td></td>
<td>Timeliness</td>
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<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>Cost</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Efficiency</td>
<td>Resource Efficiency</td>
<td></td>
<td></td>
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<td>X</td>
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<td></td>
<td>Time Efficiency</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td></td>
<td>Cost Efficiency</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>Reliability</td>
<td>Reliability</td>
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<td>X</td>
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<td></td>
<td>Failure Frequency</td>
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<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Recoverability</td>
<td>Time to Failure</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td></td>
<td>Time to Recover</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<tr>
<td></td>
<td>Maturity</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Permissibility</td>
<td>Authority</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Availability</td>
<td>Time to Shortage</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time to Access</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Availability</td>
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<td></td>
<td>X</td>
</tr>
</tbody>
</table>

A quality factor is associated with a set of quality metrics used in evaluating the quality factor. A short description of each quality factor is provided in the following.

Throughput in general means the amount of work, people, or things that a system deals with in a particular period and this factor is defined for event, input and output; Event Throughput refers to the number of events handled during an observation interval by an activity [45]; Input Throughput indicates the number of inputs processed by an activity in a time interval; Output Throughput also indicates the number of outputs delivered by an activity or a set of activities during an observation interval.

Cycle time is defined as total time needed by an instance of an activity to transform a set of inputs into defined outputs [46]. Timeliness simply means timely convenience [47] and this factor is defined for input and activity. Input Timeliness indicates having the input timely and available when it is required [48] delay and consequently Activity Timeliness refers to executing an activity with no delay.
Cost is defined as the amount of money that is needed in order to buy, pay for, or do something and this quality factor is defined for input and activity; Activity Cost represents the cost associated with the execution of an activity in a business process; Input cost correspond to the amount of money spent for acquisition of the input.

Efficiency in general means skillfulness in avoiding wasted time and effort [47]. Activity Resource Efficiency factor of an activity, which shows how much an activity is successful in avoiding wasted resources. By resource we mean non-functional resources. Cost efficiency as a quality factor is specified for Activity and Input concepts. Activity Cost efficiency shows how much an activity is successful in avoiding wasted budget. Input Cost efficiency indicates if acquisition of the input is happened within the determined budget. Activity Time Efficiency indicates how much an activity execution is successful in avoiding wasted times.

Reliability is the quality of being dependable or reliable [47]. Activity Reliability is referred to the probability that an activity will execute without failure under a given environment and during a specified period of time.

Failure simply means an act that fails and Activity Failure Frequency indicates the number of failures occurred during an activity execution within a given time period. Time to Failure can be considered as the duration between recovery from last failure and the current failure. Thus, Activity Time to Failure can be defined as the duration between recovery from last failure of an activity and the current failure of the activity.

The duration that a business process (or part of it) cannot be executed until the failure is recovered is called Time to Recover. Activity Time to Recover indicates the time it takes to recover an activity from a failure. Maturity is the state or quality of being fully grown or developed. Activity Maturity can be defined as the percentage of the time that an activity is executed without any failure out of the whole time of execution and failure (expressed in percentage).

Authority is defined as official permission or approval. This quality factor is defined for input and activity concept. Input Authority indicates that an input whether in form of a piece of information or a raw material etc. just can be consumed by authorized activities. Therefore, authority of an input will be violated in case of being used by a non-authorized activity. Activity Authority can also be defined as the permission of specific swim-lanes (actors) to execute an activity.

Shortage is defined as the property of being an amount by which something is less than expected or required [47]. Input Time to Shortage for an input can be defined as the duration between recovery from last shortage and current shortage. The duration that a business process (or a part of it) cannot be executed until the input is regained, is called Time to Access of an input.

Availability is the quality of being at hand when needed [47]. Input Availability is the percentage of the time that a business process has access to its required input in a time interval.

The metrics for each one of the aforementioned quality factors is are defined according to specific formulae but due to space limitations it is not possible to outline
Consider as an example the business process of producing wallets. Output (o) is Wallet. Th(wallet) indicates the number of wallets (n(wallet)) produced in a time unit. Suppose that the observed number of wallets produced in 150 hours (t) is 6000 wallets (n(wallet)). Output throughput (Th(wallet)) is calculated based on the above formula. The result of calculation “wallet throughput” is expressed by $Th_{\text{wallet}} = \frac{6000}{150} = 40$ wallet/hr. The result shows the current situation of the quality factor. Based on the result, the production line’s stakeholder(s) can see the gap between the current situation and quality goal/objective. This shows that in every hour, 40 wallets will be produced. Suppose the quality goal was defined for this quality factor as “having production rate of 47 wallets per hour” ; Based on current production rate (throughput) and other production specifications, stakeholders can decide about the way they can achieve this quality goal/objective.

Each one of the factors defined in Table 1 has associated with it a metric, which can be calculated according to a corresponding formula. This simple example serves only as a way of elaborating on the use of factors and their metrics. A full elaboration on each one of the factors as well as the intricate relationships between them that may result in complex but illuminating results, are beyond the scope of this paper.

The quality factors relate to specific concepts of the unified business process model. Thus formally, we can enrich the unified business process meta-model with these quality factors. The resulting meta-model is shown in Fig. 3 (note that this is a subset of the entire unified meta-model, focusing on those concepts that are related to quality factors).

Fig. 3. The quality meta-model
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Business process constructs are shown in white classes and quality factors are shown in grey classes. The quality meta-model can be used for quality modeling and business process redesign and can help practitioners to consider quality requirements of a business process at earliest stages of system development.

6 Conclusion and future work

The work presented in this paper is based on the following premise: (a) that quality of business processes needs to be carried out within a methodological framework that links stakeholders’ goals to quantitatively analyzable properties of specific concepts of a process, (b) that the medium through which this can be effectively done is through business process modeling, (c) that the multitude of BPM descriptive approaches could be considered at unified level upon which quality factors may be defined without needing to consider the ‘surface level descriptions’.

The outcomes of the research are beneficial to the areas of business process management and requirement engineering. In area of business process management, the approach could lead to a quality driven modeling and re-design. In the area of requirement engineering, the approach could help practitioners to consider non-functional requirements at the earliest stage.

The work presented in this paper is currently being extended in the following ways. First, the intertwining of factors and their measures in being considered so that a more holistic view of quality in business processes [49]. Second, the work establishes a strong framework upon which different methodological and technological developments may emerge such as the enhancement of existing business process modeling tools with a simulation component, the development of a workbench for analyzing measured qualities and the development of further cases on an industrial basis [50]. Third, strategic modeling approaches such as system dynamics could be coupled to business process modeling using parametric definitions according to quality criteria and experimenting with ‘what-if scenarios’ thus giving stakeholders an early view of the impact of their choices, on the behavior of a business process [51]. Fourth, the area of collaborative business process method can be considered as a valid extension in order to be able to deal with the issue of complex business processes. Handling these business processes demands for collaboration and participations of different partners in modeling business processes [52, 53].

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