

# Ontology for Quality Specification in Requirements Engineering

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**Abstract**—The field of Requirements Engineering (RE) is arguably one of the most crucial areas in the development of systems in support of organisational structures and processes. Eliciting, negotiating, analysing and validating are RE processes that rely on appropriate abstraction mechanisms. This paper focuses on a specific modelling approach, that of Business Process Modelling (BPM), and the use of a specific ontology for modelling and evaluating quality aspects of business processes. This business process ontology provides an explicit specification of the shared conceptualization and understanding of enterprises between IT and non-IT experts. Specification and measurement of requirements based on an ontology fosters communication between experts. This paper proposes an approach that drives specification and measurement of quality requirements. Application of the proposed approach is illustrated for a simplified version of a business process.

**Keywords**- *Ontology; Quality requirements; Quality specification; Quality measurement; Business process; Business process modelling.*

## I. INTRODUCTION

Arguably the most significant issue in systems development is getting requirements right and transforming them without information loss into a semantically rich specification, from which various types of software artefacts can be derived [1]. An important challenge for requirements engineering (RE) is to facilitate communication between non-IT and IT specialists [2]. An ontology designed for this purpose with well-defined semantics at the appropriate level of abstraction is the challenge this paper addresses.

Currently, enterprises are described in terms of business processes models. Linking business process quality requirements with business process concepts enables IT and business experts to define their requirements collaboratively at a common abstract level during the earliest stage of design and development of information systems.

The motivation for the work this paper presents is to use ontological constructs to facilitate specification of quality requirements based on business process concepts; in other words, *ontology driven quality requirement specification*. In addition to quality requirements, annotation of business process models with related information artefacts using

domains' vocabulary leverages different concepts (goals, rules, patterns, motivation, etc.) into the scope of business process ontology [3, 4]. Each business process modelling (BPM) language provides an ontology consisting of a set of concepts. A systematic realization and representation of concepts and relationships between the concepts of different BPM languages in a business process ontology [5], is essential. The formalism of a generic purpose modelling language (GPML) e.g. UML class diagram provides the ontology description. The approach is exemplified using an example from a real-life business process in an industrial case.

The paper is organized as follows: Section 2 presents a brief summary of related works. Section 3 elaborates on ontologies, in particular business process ontologies and their application and introduces an ontology driven approach to specification and evaluation of quality of business processes. Section 4 illustrates the proposed approach for a business process. The paper concludes in Section 5 with a number of observations, reflections and suggestions for future work.

## II. RELATED WORKS

Quality has been the topic of research in several closely related disciplines as requirement engineering, software engineering, workflow analysis, industrial engineering, system dynamics and discrete event simulation. Different levels of granularity can be considered for realizing and measuring quality in an enterprise involving many organizational layers from the very general i.e. organization-wide quality to concepts of business processes. Synoptically, investigation of the most relevant approaches in following aspects will be considered in this section: (A) the way they are being practiced (methodology e.g. systematic or ad hoc), (B) representation of business process and quality requirement (modelling and language dependency), and (C) generalizability of the approach (application) is conducted in this section.

### A. Methodology

While “focus of work”, “required inputs”, “expected outputs” and a “set of phases” are prescribed with details in an approach, the approach is considered to be systematic in terms of methodology (e.g. [14], [6], [7], [8], [9]); otherwise

the approach is considered to be ad-hoc in terms of methodology (e.g. [10], [7], [11])

Wolter et al. [12] deploy a method to assign elements of their security model to a process model. Capturing quality dimensions of a business process in form of a framework are considered by Heravizadeh et al. [13]. A framework for evaluation of business process quality is introduced by Kedad et al. [14]. A requirements engineering framework with the aim of allowing active stakeholder participation is introduced by Donzelli et al. [8]. Pourshahid et al. [15] introduce a framework to measure and align processes and goals subjectively. In their work, key performance indicators (KPI) are added to user requirement notation (URN) together with explicit goals for each business process. A scenario-based methodology and a toolset for BPM and analysis is introduced by Glykas[9]. The approach defines and measures KPIs in qualitative as well as quantitative manner.

The approach by Firesmith [7] proposes a checklist of questions over which defects in software-intensive system architectures would be realized. Measurement is included in the structure although the process toward the measurement is not discussed. Lohrmann et al[11] provide a definition for business process quality and introduce business process quality model. There are no details provided on how measurement should be conducted

**B. Modelling and language dependency**

Modelling is concerned with the way an approach represents a business process. The consideration here is the use of formal or semi formal languages in the representation (e.g. [8],[13],[14], [6],[16].) Language dependency examines this fact if an approach’s focus is on a specific language. Works by Kedad et al [14] and Said-Cherfi et al. [17] are not tied to a specific modelling language.

Heinrich et al [18] use the quality characteristics and attributes of processes. They distinguish on the basis of the ISO/IEC standard for software quality [10] to enhance BPMN. Saeedi et al [14] propose a set of quality requirement factors for BPMN concepts. Role Activity Diagram notation is considered for representation of business processes by Aburub et al. [16]. The strategic rationale for the choice of business processes to be specified in BPMN models and described in terminology familiar to business people are considered by Decreus et al. [6].

**C. Application**

The application aspect is concerned with the target of the approach. Generic approaches can be applied to all or most situations (e.g. [19], [14]). Specific approaches (e.g. [12], [16]) are dedicated to a particular class or application or business sector.

Wolter et al. [12] focused on security requirements. Aburub et al. [16] introduced an approach in remodelling business processes for identification and inclusion of Non-Functional Requirements (NFRs) for a specific case. With the focus on quality of business process model the approach

by Said-Cherfi et al. [17] considers ontologies in a number of specific domains.

There are variations in methodology, in the specification approaches used and the target application of these quality approaches. The desire is to provide an approach, which is systematic and well-structured, generic enough and not tied to a specific domain or situation, and while considering formal expression of business processes is not tied to a particular BPM language. The majority of approaches discussed above are based on the assumption that a formal language (e.g. BPMN) is used to describe business processes, the majority of which use one representation scheme. A few are language independent. Some provide systematic way of working and some are generic enough to be applied in generic situations. The approach introduced in this paper in some ways complements and in others extends existing approaches by emphasizing a well-structured way for specification and objectively measurement of business processes, which is generic in application and language independent.

**III. THE ONTOLOGY DRIVEN APPROACH**

During requirement analysis, an important consideration is to understand current business processes. In this effort, business process modelling plays a key role. Therefore,

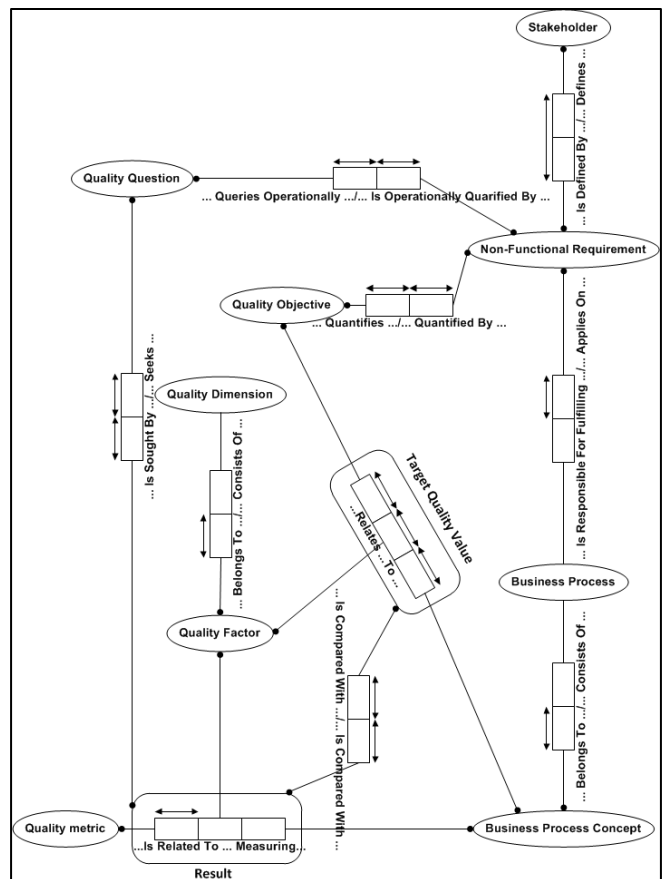


Fig 1. Conceptual Framework for Business Process Concept Quality Specification and Measurement (in ORM)

having an ontology for quality aspects of any business processes, using a corresponding model, would go a long way to unifying the field and to facilitating a more systematic way of treating quality.

Synchronization between requirements and business process models requires a common basis. This common basis can be presented in an ontology confined to requirement aspects. The ontology construction is to provide an explicit representation of knowledge, that can be understood by both computers and people [20].

A business process ontology represents an abstraction of business process concepts, that is universal and not dedicated to one single BPM language. The business process ontology can be designed for business analysts to describe functional as well as non-functional requirements in a single place [21].

Another applications of a business process ontology *confined to quality aspects* is that stakeholders to define their desired requirements in a higher level (meta-model) rather than in specific business process specifications. A business process ontology, *enriched with the desired requirements*, can act as a reference model for future enriched business processes generations.

This ontology can also act as a repository. This repository can have several applications: (a) to represent models created via deploying any of the constructing modelling languages as its instantiations, (b) to be a reference between multiple business process modelling approaches of the same project, (c) to provide the basis for a repository of emerging business process models irrespective of the language used, (d) to be extended to a knowledge base, (e) to facilitate direct implementation, and (f) to be a reference model fostering incorporation of stakeholders' requirements.

This paper proposes an ontological approach to specification and measurement of quality requirement for business process concepts. This approach includes quantitative metrics for business processes in its specifications. The conceptual framework of the approach is shown in Fig. 1. The framework is presented in Object Role Modelling (ORM) notation [22].

The "conceptual framework" encompasses a set of concepts that link requirements to specific business process concepts, their factors and corresponding metrics. Fig.1 depicts that "Requirements", are associated with "Business Processes Concept". A "Requirement" is expressed by a "Stakeholder" and is operationally queried by a set of "Questions". Operationally querying "Requirements" are linked to components that participate in measuring achievement of the "Requirement". "Question" essentially is a query on the 3-nary relationship of "Business Process Concept", "Factor" and "Metric" as depicted in the objectified relationship "Result" related to "Question".

A "Business Process" consists of a set of "Business Process Concepts". A business process "Factor" is an inherent property of a "Business Process" or a "Business

Process Concept" that can be measured quantitatively by "Metrics".

The gap between "Objective" and the observed current performance through "Question" is shown in the relationship of "Target" and "Result". Several "Metrics" can be associated to a single "Factor" as there might be several ways for evaluating it. Different stakeholders can indicate different metrics based on their needs [14].

The contribution of this framework is in the establishment of a set of conceptual structures that are independent of descriptive languages, or applications. Applicability of the framework is illustrated for an example of business process in the next section.

In addition to specification and measurement of quality requirements for individual business process concepts, there is a need for measuring requirement fulfilment by a business process as a whole or a part of business process. A business process ontology can foster objective evaluation of the degree to which a quality requirement for a business process is achieved based on achievements of its individual concepts.

To evaluate business processes on the basis of the result of its individual constructs, analysts need to break down process models into more manageable and easily measurable parts. Realization of reusable patterns makes this task more straightforward [23]. A business process ontology defines business process concepts and the relationships among them. In this paper, the five generic patterns of "sequential", "exclusive", "parallel", "loop" and "inclusive" are implemented [5]. Higher degree business process are described as a combination of these patterns [23]. Semantics of individual patterns determine the computation rules and formulas for evaluation of the pattern based on its constructing concepts.

Due to space limitation, discussion on the method, rules and mathematical formulas for measurement (computation) and estimation (prediction) of quality of business processes based on its constructing concepts are not included in this paper. This application of the ontology driven approach is illustrated via an example in the next section.

#### IV. DEMONSTRATION OF APPLICABILITY

The applicability of the approach this paper proposes is demonstrated for a simplified version of business process, namely "Accepting clients" from an anonymous enterprise. The business process is known to this enterprise.

##### A. Evaluation of quality of individual concepts

First, in a more visual way, the instantiation of the framework is provided (Fig. 2). Fig. 2 illustrates not only the business process in terms of a model but also provides examples of the related elements for quality specification and measurement considering the business process concepts. Later, the conceptual framework is instantiated (Fig. 3) to demonstrate its application relates to the example in form of an ORM model.

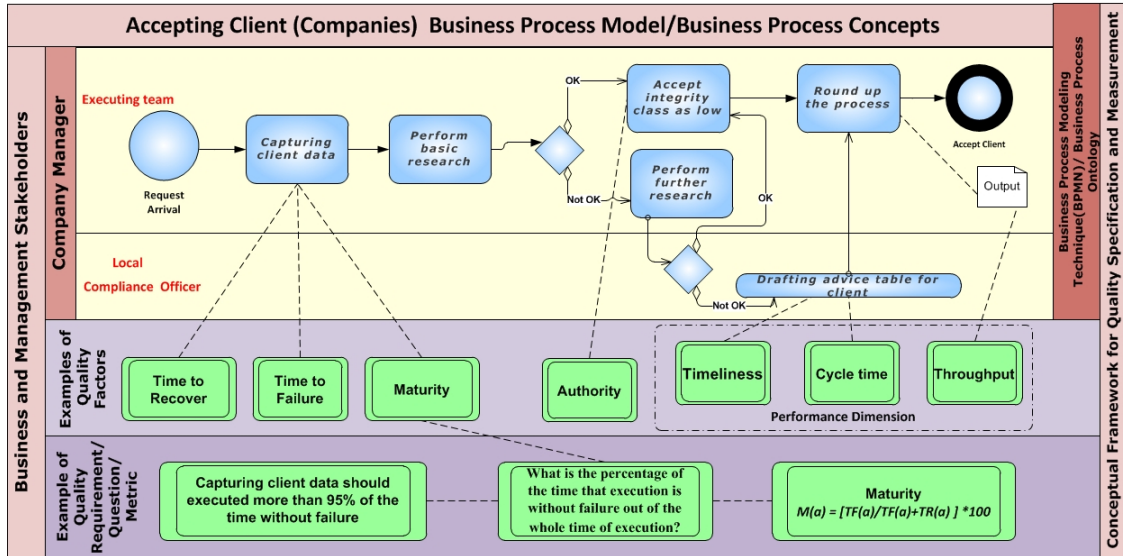


Fig 2. Accepting Client Business Process and Examples of Quality Factor, Requirement, Question and Metric

As can be observed from Fig. 2, there are different departments/roles involved in the process. The process trigger is arrival of a request to accept a client. To accept the client, a set of activities is performed in a predefined order. Some related quality factors are shown in Fig. 2 namely,

time to recover, time to failure, maturity, authority, timeliness, cycle time, and through put. Quality factors are assigned to the business process concepts via dashed lines as shown. For the matter of distinction, quality factors are shown in a separate box below the example. The “business process” is presented via applying BPMN as a “Business process modelling language” supported by a business process ontology e.g. [5].

Fig. 2 shows that the quality requirement of “Capturing client data should be executed more than 95% of the time without failure”, is associated with the business processes concept of “Capturing client data”; this concept belongs to business process of “Accepting client”. The Requirement is expressed by a the “Company manager” as the stakeholder and is operationally queried by questions of “What is the percentage of the time that execution is without failure out of the whole time of execution?” The quality factor “maturity” can be measured by a quality metric expressed as following:

$$M(a)=[TF(a)/TF(a)+TR(a)]*100 \quad (1)$$

Where “a” denotes the “Activity”, TF(a) is the “Time to Failure” and TR(a) is the “Time to Recover”.

Applicability of the proposed approach is also demonstrated via instantiation of the conceptual framework (Fig. 3) with regards to the example. The instantiation is focused on quality requirement of “ capturing client data should be executed more than 95% of the time without failure”. Instances are introduced as “roles” in “fact tables”. Information in the fact tables is inline with the example described earlier and provided in Fig 2.

*B. Evaluation of quality of a part of business process*

Formula (1) is for calculation of the maturity of a single activity as an individual concept of a business process. Besides single concepts, there is a need for computational formulas enabling one to evaluate quality of a business Measurement of maturity of a part of business process (Fig.

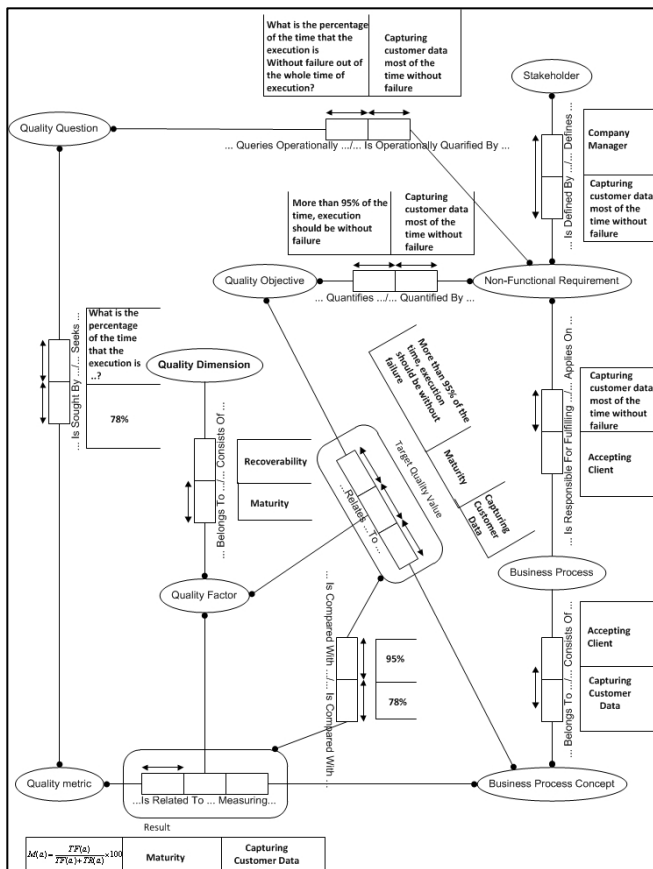


Fig 3. Conceptual Framework Instantiation for Accepting Client Process (Capturing Client Data Should Be Executed More than 95% of the Time Without Failure

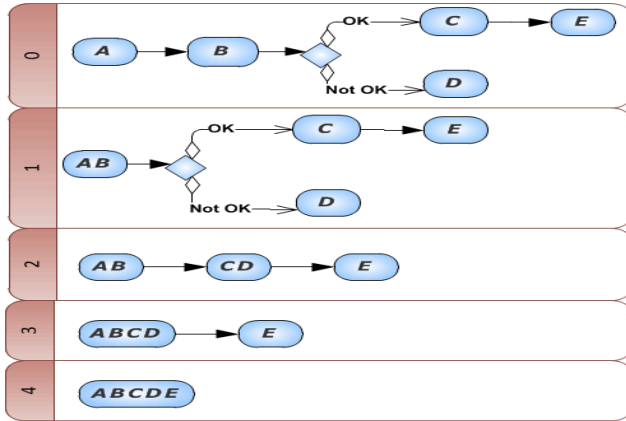


Fig 4. Business Process Reduction Stage

2) executed by “executing team” is considered in this example. The lane under investigation encompasses a flow of activities linked together either with sequential or exclusive relationship; in sequential and exclusive patterns composed of smaller parts.

Inspired by an algorithm offered for workflow reduction in [24], as can be observed in Table 1, the recognized patterns can be reduced to more manageable and easily measurable concepts. Different formulae are introduced for the different patterns. Reduction is performed in different stages. The end result is one single activity (Fig.4). Either estimation or measurement of the activity flow is possible. Based on the reduction patterns and the formulae introduced in Table 1, four steps toward complete reduction are involved in the calculation of maturity of the flow of activity (Fig. 4). For the ease of communication, the name of each activity is replaced simply with just a capital letter. Each phase involves one reduction. The result of reduction of each set of two activities is presented as another activity. The resulted activity name is indicated as the combination of the labels of the constructing activities; for example in stage 1, reduction of sequential patten of “A→B” is a single activity namely “AB” and so on.

For the purpose of simplification, the same value is specified for the maturity measurement and estimation of the value of an activity before reduction. In the examples provided, measurements, assume the client is to be accepted. Probability of activity “C” is 75% and consequently

TABLE I. REDUCTION FORMULAE

		Pattern		
		Sequential	Exclusive	
Factor	Calculation			Actual
				Reduced
Maturity	Measurement	$M(ab)=M(a_a) \times M(a_b)/100$	$M(a_{1n})= M(a_a)$	
	Estimation	$M(ab)=M(a_a) \times M(a_b)/100$	$M(a_{1n})=[\sum_i^? p(a_i) \times M(a_i)]/100$	

TABLE II. CALCULATION REULSTS

Activity	Reduction Formula		Result	
	Measurement	Estimation	Measurement	Estimation
A	----	----	100	100
B	----	----	95	95
C	----	----	80	80
D	----	----	100	100
E	----	----	75	75
AB	$M(A) \times M(B)/100$		95	95
CD	$M(C)$	$[M(C) \times 75 + M(D) \times 25]/100$	80	85
ABCD	$M(AB) \times M(CD)/100$		76	80.75
ABCDE	$M(ABCDE) \times M(E)/100$		57	60.56

probability of activity “D” is 25%.

Table 2 provides the formulae for calculation of the activities resulting from each of the stages of reduction for two cases of measurement and estimation. The calculation is based on the formula introduced in Table 1.

As demonstrated, calculation of requirement fulfilment of a business process can be based on results of constructing concepts. This provides an objective and valid result for the business process.

V. CONCLUSION AND FUTURE WORK

This paper assumes that the quality of a business process can be defined by the degree to which pre-defined properties of pre-defined concepts identified within a business process are linked to stakeholder requirements. The methodological stance of the approach proposed in this paper is *systematic*. Stakeholder goals are transformed to objectified components, a quality objective and a quality question, that are directly linked to quality factors for a pre-defined business process concept. The approach relies on *formal* expressions of business processes in business process models. At the same time, it is *independent* of any language. The utility of approach is *generic*, i.e. applicable to any application and within any domain.

The outcomes of this research are beneficial to the areas of business and management, requirement engineering, software engineering, business process modelling and service-oriented architectures. In the areas of requirement engineering and software engineering, these results make it possible for practitioners to consider quality requirements at the earliest stage.

This paper establishes a strong framework upon which different methodological and technological developments may emerge such as an enhancement of existing business process modelling tools with a simulation component, the development of a workbench for analysing measured qualities and the development of further cases on an industrial basis [25]. Future research will focus on extensions and developments both in theoretical and practical perspectives. Exploring possibilities to enhance

existing industrial business process-modelling tools with quality evaluation extensions is currently subject of research. Also, strategic modelling approaches such as system dynamics are to be coupled to business process modelling 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 behaviour of a business process [26].

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