The PQUAL Open System Quality Model

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Quality assessment of open business enterprise systems is very important because those platforms play a central role in the organizations that implement them. The current paper proposes a new easily applicable software quality model called PQUAL that evaluates the quality of such systems. The quality characteristics are identified and analyzed using the ISO/IEC 9126 international standard as a starting point. The paper develops metrics to measure the quality level for the characteristics. The PQUAL model is applied to compare the quality of the DocuMentor and YAWL platforms.
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1 Introduction

Modern businesses employ complex business processes that involve documents, people and internal or external information systems in order to perform their activities. These processes can be automated efficiently by using open business enterprise systems – OBES. An OBES is an integrated set of subsystems that support operations, management and decision making, composed of three extensible subsystems: *client* - allows the final user to interact with the data and business processes managed by the system, processing - implements system operations, manages process instances, exposes its functionality to the external systems using a well-defined interface and *storage* - stores the data manipulated by the business processes using a user defined structure. An OBES architecture called BWS and the DocuMentor platform that implements it are presented in [1].

Because every OBES plays a very important role inside the organization where's implemented, assessing its quality is critical. The quality of a software product is defined as the set of characteristics that allows it to meet the expressed or implied needs of the users. A quality characteristic is a set of properties of software by which the quality can be described and assessed. Characteristics can be decomposed into several levels of sub features.

Generic quality standards such as ISO / IEC 9126 represent starting points for defining specific quality assessment models. The development of a specific quality model is useful for both the developer (to determine competitive advantages) and the client (for product selection).

The quality model reveals the complex interdependence, subordination, decomposition and aggregation relationships existing between the quality characteristics. According to [2], in order to be functional, a quality model must satisfy the following requirements:

- complete: address all aspects relevant to quality;
- hierarchic: the characteristics must be decomposed in sub elements quantifiable using metrics;
- consistent: the characteristics mustn't contradict one another.

The ISO/IEC 9126 standard defines six characteristics that describe, with minimal interdependencies, the product quality. The characteristics proposed by the standard are: functionality, reliability, efficiency, usability, maintainability and portability.

The standard model is a generic one, suitable for a vast array or software products. In order to be used, the model must be adapted for the specific software category.

The PQUAL model was developed with the specific goal of measuring with minimal effort on part of the model user the quality of open business enterprise systems. It measures the usefulness of an OBES platform as a business process automation and optimization tool inside the enterprise.

The following sections identify the quality characteristics relevant to an OBES, construct metrics to evaluate the characteristics and apply the model to assess the quality of the DocuMentor and YAWL platforms.

2 Quality Characteristics for OBES

The development of the PQUAL started with a careful assessment of the generic model defined ISO/IEC 9126. The relevance for an OBES of each main characteristic was analyzed. Each characteristic was divided into relevant sub characteristics and weights were determined to quantify their relative importance.

Functionality is defined by the standard as a set of attributes that express the existence of a set of functions and their specific properties. Each function represents a part of the implementation that satisfies an implicit or explicit client requirement. The sub characteristics of functionality are suitability, accuracy, interoperability, functionality compliance, security.

Suitability expresses the capacity of the platform to implement the relevant domain features. The features are classified in mandatory core features and optional features.

An open business enterprise system coordinates and executes operation processes that involve peoples, application and information sources. The process management is implemented using a workflow management system. The core features identified for these features are:

- Process description using a formal workflow language;
- Execution of workflows specified using the description language using a workflow execution engine
- Interface with the relevant actors (human or other information systems) involved in the workflow execution.

The optional features relevant for an open business enterprise system are:

- Data storage using a module that permits the storage of all data manipulated by the workflow instances;
- Dynamic workflow definition updates;
- Document imaging and processing features that allow scanning and manipulation of paper documents in workflow instances;
- Custom data collection forms that can be designed by the end user.

The features used to establish the platform suitability for an OBES are synthesized in Table 1. Every optional feature has an associated weight according to its importance. The core features don’t have an associated weight because the absence of any of these features would exclude the platform from the OBES category, so no further quality evaluation should be performed using the PQUAL model.

Table 1. Core and optional OBES features

Category	Functionality	Weight
Core	Usage of an executable workflow language	*
	Process execution based on the defined language	*
	Interfacing with human and system actors	*
Optional	Storage and retrieval for associated documents	0.30
	Dynamic workflow definition updates	0.30
	Document and imaging processing	0.20
	Custom data collection forms	0.20

Accuracy is the platform capability to execute the platform functions correctly and in accordance to user specifications. The most important feature of an OBES is execution of workflows defined using a specific language. The relevant accuracy characteristics identified for an OBES are:

- The existence of formal semantics for the workflow language;
- The system ability to detect control flow

problems automatically.

Interoperability represents the capability of a system to interact with other actors involved in the managed process. The attributes that define the interoperability of an OBES are:

- Ability to expose the implemented operations using a standard protocol, such as SOAP or JSON-RPC, and to offer workflow instance access;
- Ability to invoke operation in external systems using standard protocols from workflow definitions;
- Ability to extend the workflow language with the statements required to interact with other actors in nonstandard ways.

Security represents the system ability to prevent deliberate or accidental unauthorized access to programs and data. For an OBES this characteristic is harder to meet than in classic enterprise systems because of the complexity and larger exposure to external systems.

To ensure the system security, the platform must address the following aspects:

- Authentication – the identity of every user or system accessing the platform must be established using secure credentials;
- Authorization – the platform must verify that every operation is authorized using the authenticated identity and authorization rules defined by the administrator;
- Audit – the platform should record every transaction that affects the stored data to ensure non-repudiation and recover from unauthorized operations;
- Communication channel security: the platform must be able to secure all communication channels to client applications and external systems.

Reliability is defined as a set of attributes that characterize the platform ability to maintain its level of performance under stated conditions for a stated period of time. The most important characteristics for establishing the reliability of an OBES are:

- Fault tolerance: the platform ability to maintain a stated performance level in the event of a failure;
- Recoverability: the ability to reestablish the baseline performance level and recover data after a failure occurs.

Fault tolerance implies maintaining a stated performance level in the event of a failure generated by an internal (generated by a design or implementation fault) or external problem (such as OS errors, hardware errors or power failures). Generally, fault tolerance is achieved using multiple redundant processing nodes. A failure in one of the nodes mustn't affect the functionality of other nodes. When one node fails the load balancing system must be able to redirect the requests to the remaining active nodes. The system must be capable of isolating the errors that can occur in a workflow instance. A fault inside one instance must not affect the execution of other instance or any shared data. When an error occurs, the system must ensure data integrity and be able to restart the process instance.

An important requirement for an OBES is the ability to report errors. Error reporting can be implemented locally (on every workstation or processing node) or centrally. Centralized error reporting is preferred because the faults can be discovered faster by monitoring the central error reporting location.

Fault tolerance, recoverability and error reporting are very important for an OBES because the system usually plays a critical role inside the enterprise.

Efficiency is defined by [3] as a set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions. For an open business enterprise system there are two major factors that affect efficiency:

- Parallel processing: the system must be able to use multiple processing nodes in order to process efficiently a large number of workflows;
- Distributed data storage: for parallel efficient workflow execution the storage subsystem must be able partition the data across multiple database system in order to avoid the performance problems generated by workflow concurrency.

Usability is a set of attributes that bear on the

effort needed for use, and on the individual assessment of such use, by a stated or implied set of users – [3]. Quantification of usability is made difficult by the dependency between the selected users and their perception of 'ease of use'. Usability is the most subjective and hard to evaluate quality characteristic.
Software usability is the subject of many international standards (the most important one is ISO 9241-11), directives, empirical and theoretical studies and is considered an important factor of software quality. According to ISO 9241, the attributes that determine the usability of a software product depend on the user and task category and on the execution environment. A software product doesn't have an intrinsic usability level that can be determined by analyzing the product in isolation. This level is determined by studying the product usage in a specific context.
There are two important user roles identified for open business enterprise systems: developers and final users. Developers are specialist users that create and maintain workflow definitions, write scripts to automate tasks and develop extension modules. They are willing to invest a relatively large effort to understand the system. Final users are business users that interact with the system in order to perform their normal assignments inside the organization. They are not willing to invest a significant amount of time in learning to use the system and need a simple task oriented interface to guide them through the system without the need for additional documentation or technical support.
The main usability characteristics included in PQUAL are presented in table 2. The characteristics are classified according to the user role.

Table 2. Usability characteristics

User role	Associated features
Developer	• Workflow designer • Task automation using scripts
Final user	• OS specific client for accessing the platform features • Web client • Easy work item identification • Multiple criteria retrieval for workflow instances

Maintainability is defined as a set of attributes that bear on the effort needed to make specified modifications. The need for change arises from the necessity to correct errors or adapt to a new business requirement. To minimize the effort and risks associated with the changes, an OBES must have the following attributes:

- analyzability: the capability to allow rapid identification of the elements that need to be changed in order to implement a business use case;
- stability: the capacity of the system to isolate the impact of changes across parts of the system that are not directly related;
- testability: the property of the system to allow easy testing for both the core system and the workflow definitions.

In the case of OBES there are two maintainability levels: workflow and the execution platform. At the workflow level there are two important attributes:

- the possibility to extend the language with new processing instructions in order to implement new processing components and to facilitate bidirectional integration with other systems;
- the ability to create new control flow instructions to implement patterns that are not available in the base language, but are necessary to correctly implement the business process.

The ability to extend the platform is very important to meet the maintainability requirements. These aspects must be considered from the first phases of the development. The critical attribute for platform level maintainability is the presence of an extension

framework. This framework must allow the creation of extension modules for the user interface, processing service and data storage.
Another important maintainability feature is the ability to create custom data collection forms and custom reporting. This attribute is important because it can often eliminate the need to create an extension module which requires a greater effort and implies added complexity.
Portability is defined by the standard as a set of attributes that bear on the ability of software to be transferred from one environment to another. In the case of an OBES, by environment we understand both the hardware – software combination and the business environment in which the system operates. The portability relative to the hardware – software environment is composed of two different aspects:

- the client application portability across client platforms;
- the database and processing service portability across server platforms.

The portability of the system across organizations and industry verticals is determined by two attributes:

- domain agnostic implementation of base capabilities (control flow, simple data processing) that are needed to execute workflows;
- presence of an extension framework that allows the implementer to customize the system for the target organization or industry.

Table 3 synthesizes all the quality characteristics and sub-characteristics included in the PQUAL model. These characteristics enable the comparative evaluation of set of OBES.

Table 3. PQUAL quality characteristics

Characteristic	**Sub-characteristic**
Functionality	Core functionality
	Optional functionality
	Security
Reliability	Fault tolerance
	Error handling and reporting
	Recoverability
Efficiency	Parallel processing
	Distributed data storage
Usability	Workflow designer
	Task automation
	Client workflow tools
	Easy work item identification
	Multiple criteria retrieval for workflow instances
Maintainability	Process adaptability
	System adaptability
Portability	Client application portability
	Service and database portability
	Adaptability for different verticals

The characteristics identified in the PQUAL model can be used analyze any system that respects the requirements for an OBES. The level of quality for such a system is determined using the PQUAL quality metrics.

3 PQUAL Quality Metrics

In order to determine the quality level for a platform is necessary to define metrics that can quantify each quality characteristic. Currently there is universally accepted metric system that can be used for OBES evaluation. ISO 9126 offers only general guidance in establishing metrics for a particular type of systems.
Inside the PQUAL model there are four types of metrics used to determine the quality level [4]:

- presence: identifies whether an attribute is present in a component or not; represented by a boolean associated numeric values 0 and 1;
- duration: represents the time interval necessary for a user or the system to perform a specific operation measured in seconds;
- qualitative: is a subjective measure described by an integer variable that can take any of the following values: 0 - Very Low, 1 - Low, 2 - Medium, 3 - High, 4 Very High
- percent: is measured by an integer variable with values between 0 and 100.

All characteristics defined inside the PQUAL quality model have associated metrics used to determine the quality level for an OBES.

The functionality metrics quantifies the degree in which the evaluated platform provides the necessary business process automation features.

The functionality implementation percent - GI is defined in the PQUAL model by the formula:

$$GI = \sum_{i=1}^{nfgi} pf_i \cdot implf_i \cdot 100$$

where:

nfgi - number of considered features;

pf_i - weight associated with feature i, with the property that

$$\sum_{i=1}^{nf} pf_i = 1$$

$implf_i$ - implementation of feature i with values:

0 – not implemented

1 – fully implemented.

Table 4 shows the metrics used to evaluate the functionality of an OBES. Weights used to compute the *Optional functionality implementation percent* metric are given in Table 1.

Table 4. Functionality metrics

Sub-characteristics	Metrics	Type
Core functionality	Complete core functionality implementation	Presence
Optional functionality	Optional functionality implementation percent	Percent
Security	User authentication and authorization	Presence
	Audit	Qualitative
	Communication channel security	Presence

Table 5 shows the metrics used for reliability evaluation of open business enterprise systems.

Table 5. Reliability metrics

Sub-characteristics	Metrics	Type
Fault tolerance	Fault tolerance features	Qualitative
Error handling	Error handling and reporting	Percent
Recoverability	Recoverability features	Qualitative

The fault tolerance and recoverability are based on the study of the system architecture and are quantified using a scoring system that assigns a numeric value to the qualitative findings as following:

0 – very low;

1 – low;

2 – medium;

3 – high.

The aspects analyzed for fault tolerance are the presence of node and process redundancy and isolation mechanisms. For recoverability the main characteristics are the load balancer ability to redirect request in case of node failure and the ability to monitor and recover failed workflow instances. In order to increase the system reliability all nontrivial errors must be recorded.

The main factors that affect the efficiency of an OBES are the efficient parallel processing of workflow instances using multiple nodes and distributed storage for process data. The presence of these features is critical for platform performance.

Table 6. Efficiency metrics

Sub-characteristics	**Metrics**	**Type**
Parallel processing	Scalability using multiple processing nodes	Presence
Distributed data storage	Scalable distributed data storage ability	Presence

The inherent complexity of an OBES and the presence of different user categories make the usability evaluation a very challenging task. Table 7 shows the metrics used to evaluate the usability level inside the PQUAL model.

Table 7. Usability metrics

Sub-characteristics	**Metrics**	**Type**
Workflow designer	Workflow designer presence	Presence
Task automation	Automation features using scripts	Presence
Client workflow tools	OS specific client	Presence
	Web client presence	Presence
Easy work item identification	Easy work item identification	Qualitative
	Mean time for current work item identification	Duration
Multiple criteria retrieval for workflow instances	Multiple criteria retrieval for workflow instances features	Qualitative
	Mean time for workflow instance retrieval	Duration

The mean times are calculated using a representative user sample group.
The maintainability for open business enterprise systems is evaluated by considering the presence and features of the extensions mechanisms at the platform and workflow language level. Table 8 presents the PQUAL metrics used for maintainability evaluation.

Table 8. Maintainability metrics

Sub-characteristics	**Metrics**	**Type**
Process adaptability	Ability to add new control instructions for data processing and system integration	Presence
	Ability to add new control flow instructions	Presence
System adaptability	Plug-in system	Qualitative
	Custom data entry forms	Qualitative

The most important portability characteristics for an OBES are the ability to use different platforms (for the client, services and database) and the adaptability for different industry verticals. The platform coverage is determined using weights proportional to platform market share.
The PQUAL model defines the *Client platform coverage – GAAC* metric as:

$$GAAC = \sum_{i=1}^{ngc} pu_i \cdot es_i \cdot 100$$

where:
ngc - number of client operating systems considered;
pu_i - market share for the client operating system *i*;

es_i - the ability of the evaluated OBES client applications to run on OS *i* with:
0 – no support;
1 – full support for the OS.
The *Server platform coverage – GAS* metric is defined as:

$$GAS = \sum_{i=1}^{ngs} po_i \cdot es_i \cdot 100$$

where:
ngs - number of server platforms considered;
po_i - market share for the server platform i;
es_i - the ability of the evaluated OBES server applications to run on OS *i* with:
0 – no support;
1 – full support for the OS.
Table 9 presents the PQUAL portability metrics.

Table 9. Portability metrics

Sub-characteristics	Metrics	Type
Client application portability	Client platform coverage	Percent
Service and database portability	Server platform coverage	Server platform coverage
Adaptability for different verticals	Generic instruction set	Presence
	Ability to extend the system to meet the requirements for different verticals	Presence

The weights used for the platform coverage metrics are derived from the current market share of the respective platforms. Table 10 shows weights determined using data from [5].

Table 10. Client and server platform weight

Platform	Weight
Client platforms, *ngc = 7*	***pu*$_i$**
Microsoft Windows 7	26.35%
Microsoft Vista	18.00%
Microsoft Windows XP	45.70%
Apple Mac OS	6.50%
Apple iOS	2.20%
Linux	0.90%
Other	0.80%
Server platforms, *ngs = 3*	***po*$_i$**
Linux	63.7%
Microsoft Windows	33.7%
Unix	2.7%

The PQUAL metrics were used to determine the quality level for two open business enterprise systems.

4 Quality Evaluation using the PQUAL Model

Quality assessment involves the systematic evaluation of the degree to which a product, process or service fulfills the specified requirements. Evaluation based on a quality model involves selection target values for the metrics used, data collection and measurements using the proposed evaluation methods, comparison with target values and results analysis.
The evaluation can be performed in any moment of the product lifecycle to create a quality profile for the target product. This profile

can be used for assessment of specifications, application development progress and for assessing the final product.

There are several techniques used to aggregate global and characteristic level measurements to obtain the final result.

The quality level for a characteristic i for platform j – NC_i^j in the PQUAL model is defined as:

$$NC_i^j = \sum_{k=1}^{nm} \frac{ob_k}{nm}$$

where:

nc - number of metrics associated with characteristic i;

ob_k - value in [0, 1] indicating the fulfillment level for the objective associated with the k metric.

System wide aggregation can be performed using several methods such as decision tables or scoring – [2]. The PQUAL model uses a scoring technique that associates a score for each quality characteristic based on its importance.

The global quality indicator for an OBES j - PQ_j is defined by the formula:

$$PQ_j = \sum_{i=1}^{ncr} pc_i \cdot NC_i^j$$

where:

ncr – number of quality characteristics defined inside the model;

pc_i – weight for the characteristic i with $\sum_{i=1}^{ncr} pc_i = 1$;

NC_i^j – quality level for characteristic i of platform j.

The PQUAL model was used to evaluate the quality of two open process aware information systems. The DocuMentor platform presented in [1] was compared with YAWL. The YAWL platform was initially developed inside Eindhoven University of Technology and Queensland University of Technology under supervision of Arthur ter Hofstede and Wil van der Aalst – [6]. The results using the PQUAL model are presented in Table 11.

Table 11. PQUAL Results for DocuMentor and YAWL Platforms

Characteristics	pc_i	**Evaluated sub-characteristic**	$NC_i^{DocuMentor}$	NC_i^{YAWL}
Functionality	0,20	Core functionality	1	1
		Optional functionality	0.8	0.3
		Security	0.88	0.78
Reliability	0,20	Fault tolerance	0.66	0.33
		Error handling and reporting	0.8	0.2
		Recoverability	0.66	0.33
Efficiency	0,20	Parallel processing	1	1
		Distributed data storage	1	0
Usability	0,15	Workflow designer	1	1
		Task automation	0	1
		Client workflow tools	1	1
		Easy work item identification	0.8	1
		Multiple criteria retrieval for workflow instances	0.72	1
Maintainability	0,15	Process adaptability	1	0.5
		System adaptability	0.66	0.33
Portability	0,10	Client application portability	0.9	1
		Service and database portability	0.34	1
		Adaptability for different verticals	0.66	0.33

Figure 1 compares the quality for the 6 characteristics levels obtained for the two platforms using the PQUAL model.

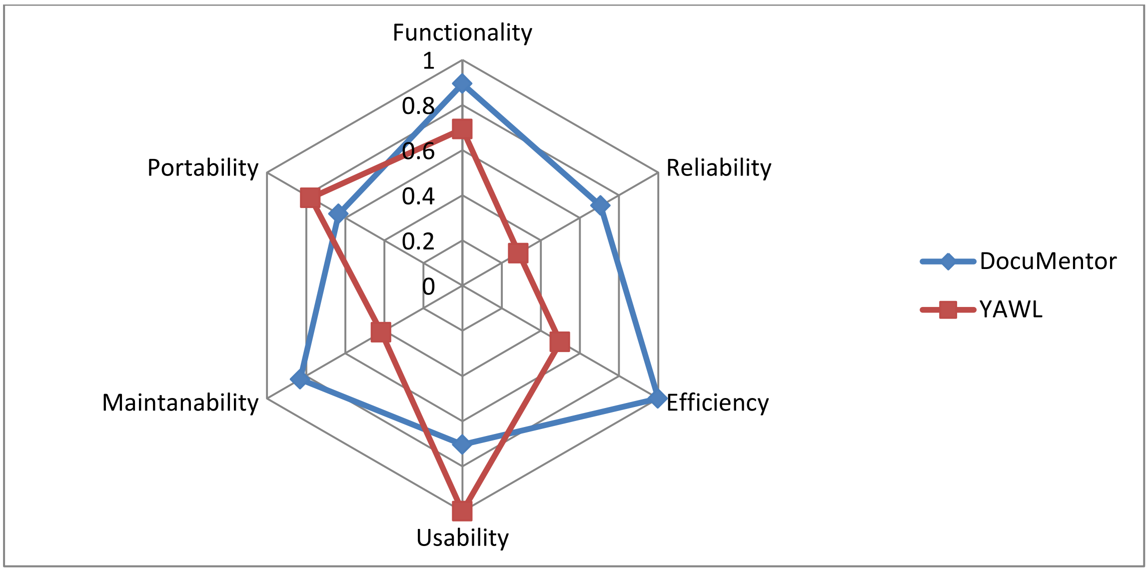

Fig. 1. Graphic representation of the evaluation results

The PQUAL global quality indicator was computed using the data summarized in table 11 and the final results are:

$$PQ_{DocuMentor} = 0.813$$

$$PQ_{YAWL} = 0.585$$

The global quality indicator shows that the DocuMentor platform meets 81% of the requirements imposed by the PQUAL model, while the YAWL meets only 58.5% of the requirements. This indicates that the DocuMentor OBES is the better instrument for business process automation inside the enterprise. The BWS based DocuMentor has obtained balanced scores across the characteristics unlike YAWL which obtained relatively low scores for maintainability and efficiency.

5 Conclusions

This paper proposed a new software quality assessment model called PQUAL. The model permits the evaluation of quality in a timely manner. The model is easy to apply because the developed metrics don't require access to the platform source code or the presence of a full implementation. The model was applied on two open business enterprise systems – DocuMentor and YAWL. The results obtained had shown that, according to the PQUAL model, the DocuMentor platform overall a better platform. The model application has revealed the weaknesses and strength of each platform. In the future, the model will be refined to include industry-specific metrics in order to evaluate the platform's suitability for particular business applications.

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