A QUALITY MODEL FOR CLOUD-BASED ENTERPRISE INFORMATION SYSTEMS

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ABSTRACT

A QUALITY MODEL FOR CLOUD-BASED ENTERPRISE INFORMATION SYSTEMS

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Organizations have migrated from on-premise enterprise information systems to Cloud-based Enterprise Information Systems (Cloud-EIS) due to the benefits of cloud computing, such as flexibility, availability on demand, and interdependence in information technology infrastructure. Accordingly, enterprises perceive the significance of the quality of Cloud-EIS for improving their businesses, and they pay more attention to selecting the suitable Cloud-EIS. Having looked at the extensive literature, only a few researchers have studied the quality of cloud-based solutions, yet their quality dimensions appear to be subjective, not well-quantifiable, and insufficient for evaluating the quality of Cloud-EIS. While this area is not completely explored, it has attracted deep interest from both enterprises and cloud providers. Therefore, this study presents a comprehensive and hierarchically-structured quality model of Cloud-EIS, which provides a systematic evaluation for diagnosing the quality of Cloud-EIS products. Consequently, the metrics of the quality model of Cloud-EIS are developed and used for quality evaluation of three Cloud-EIS products. Finally, the Analytic Hierarchy Process (AHP) method is employed in order to rank the quality factors of Cloud-EIS. The results show that the most significant quality factors are determined as security & privacy, reliability, functionality, usability and maintainability.

Keywords: Cloud-based Enterprise Information Systems, Quality Model, Cloud Computing, Analytic Hierarchy Process

ÖZ

BULUT TABANLI KURUMSAL BİLGİ SİSTEMLERİ İÇİN KALİTE MODELİ

Şener, Umut

Yüksek Lisans, Bilişim Sistemleri Bölümü

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İşletmeler bulut bilişimin esneklik, ihtiyaç anında erişim, ve bilişim teknolojileri altyapısı gerektirmemesi gibi sağladığı faydalar nedeniyle, geleneksel kurumsal bilgi sistemlerinden bulut tabanlı kurumsal bilgi sistemlerine (Bulut-KBS) geçmeye başlamışlardır. İşletmeler Bulut-KBS sistemlerinin kalitesinin iş iyileştirme yönünden etkisini anlamış ve uygun kalitede Bulut-KBS şeçmeye daha çok önem vermişlerdir. Detaylı olarak literatüre bakıldığında, sadece birkaç çalışmanın bu alanı incelediği görülmüştür; ancak mevcut çalışmaların kalite ölçütlerinin de Bulut-KBS kalitesini değerlendirmek için çoğunlukla, tam olarak ölçülemeyen, öznel ve yetersiz olduğu tespit edilmiştir. Bu alanda kısıtlı sayıda çalışma olmasına rağmen, işletmeler ve bulut sağlayıcıları tarafından önemli ölçüde ilgi görmektedir. Bu nedenle, bu çalışmada sistematik bir değerlendirme yöntemi sunan, kapsamlı ve hiyerarşik olarak yapılandırılmış bir kalite modeli geliştirilmiştir. Ayrıca, Bulut-KBS için kalite metrikleri geliştirilmiş ve üç tane Bulut-KBS ürünün kaliteleri değerlendirilerek metriklerin uygulanabilirliği gösterilmiştir. Son olarak, Analitik Hiyerarşi Süreci (AHS) metodu kullanılarak Bulut-KBS kalite faktörlerinin önem sıralaması yapılmıştır. Çalışma sonucunda, güvenlik & gizlilik, güvenilirlik, fonksiyonellik, kullanılabilirlik ve sürdürülebilirlik en önemli kalite faktörleri olarak belirlenmiştir.

Anahtar Sözcükler: Bulut-tabanlı Kurumsal Bilgi Sistemleri, Kalite Modeli, Bulut Bilişim, Analitik Hiyerarşi Süreci

To My Beloved Family

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LIST OF ABBREVIATIONS

ADAMS	Allied Deployment and Movement Systems
AHP	Analytic Hierarchy Process
API	Application Programming Interface
ASQ	American Society for Quality
ASP	Application Service Provider
BBN	Bayesian belief network
Cloud-EIS	Cloud-based Enterprise Information Systems
CPU	Central Processing Unit
CRM	Customer Relationship Management
CSMIC	Cloud Service Measurement Index Consortium
EIS	Enterprise Information Systems
ERP	Enterprise Resource Planning
ESD	Electronic System Decision
FM	Finance Management
GE	General Electric
GUI	Graphical User Interface
HR	Human Resources
IaaS	Infrastructure as a Service
IEEE	The Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
IS	Information Systems

IT	Information Technologies
KPI	Key Performance Indicators
LOGREP	Logistics Reporting Systems
Mbps	Megabits per Second
MCDM	Multi-Criteria Decision Making
ms	Millisecond
NA	Not Applicable
NIST	National Institute of Standards and Technology
OS	Operating System
PaaS	Platform as a Service
PII	Personally Identifiable Information
QoS	Quality of Service
RADC	Rome Air Development Center
SaaS	Software as a Service
SAN	Storage Area Network
SCM	Supply Chain Management
SLA	Service Level Agreement
SMI	Service Measurement Index
SUS	System Usability Score

CHAPTER 1

INTRODUCTION

With recent developments in Information Technologies (IT), firms have been prompted to implement Enterprise Information System (EIS) in order to stay competitive and survive in the marketplace. Accordingly, Customer Relationship Management (CRM), Supply Chain Management (SCM), and Enterprise Resource Planning (ERP) have been commonly implemented by organizations due to its benefits, such as processing large volume of data, handling complicated enterprise operations, and refining business quality. In spite of the substantial benefits, on-premise EIS can be heavy, expensive, and complex to use for most enterprises (Buonanno et al., 2005). In recent years, “Cloud Computing” has attracted more enterprises in using the most advanced information technologies at a reasonable level of operating cost (Sultan, 2011). The cloud computing based EIS concept, which is referred to as “Cloud-EIS” in this study, was recently introduced to improve such situations by offering competitive advantages to enterprises through flexibility, scalability, availability on demand, independence in IT infrastructure and capabilities with pay-as-you-go basis.

Since cloud-based enterprise solutions such as Cloud-CRM, Cloud-SCM, and Cloud-ERP have attracted enterprises due to their benefits, and the adoption rate of such solutions is rising (Sandhu et al., 2010); more and more cloud providers offer Cloud-EIS products. On the other hand, enterprises perceive the significance of the quality of Cloud-EIS for improving their businesses, they assign high priority on the quality, and they try to select the suitable Cloud-EIS. Having looked at the extensive literature, only a few studies examine the quality of cloud-based solutions, yet they do not target the quality of Cloud-EIS in particular, and their dimensions are mostly subjective and not quantifiable. While this area has not been fully investigated, it has attracted deep interest from both enterprises and cloud providers. Therefore, the main purpose of this study is to develop a quality model that provides comprehensive, systematic measurement method to assess the quality of Cloud-EIS products. Accordingly the following research questions of the study are determined:

- What are the quality factors of Cloud-EIS product?
- What are the weights of each factor affecting the quality of Cloud-EIS?
- What are the most significant quality factors of Cloud-EIS?
- How the quality of Cloud-EIS applications can be measured?

In this study, first of all it is explained that existing service quality models such as Servqual, E-S Qual, and Webqual are insufficient to assess the quality of Cloud-EIS. Firstly, since the service quality dimensions appear to be subjective (Benlian et al., 2011), these models do not provide an quantifiable quality metric for Cloud-EIS. Secondly, the service quality of cloud computing based solutions only considers the quality of the services provided over the Internet, and does not fully capture the software quality (IT features) of Cloud-EIS product itself. Furthermore, the cloud-specific dimensions such as elasticity should be considered as a quality factor in order to assess the quality of Cloud-EIS completely. Upon analyzing existing cloud-related quality models, it is concluded that almost all existing models are built on one of the service quality models. Although a few of them consider the IT features of cloud-based solutions as a quality factor (e.g., Functionality, reliability), they suffer from lack of quality factors. Therefore, one of the main contributions of this research is providing an extensive and integrated assessment method that concerns not only the service quality but also the software quality of Cloud-EIS products.

The study also addresses the weaknesses of the quality assessment methods provided in the cloud-related quality models such as SMI-Cloud, SaaS-Qual, Cloud-Qual, and ASP-Qual. The dimensions of these quality models are subjective, not objective (Benlian et al., 2011). In other words, the quality models relies on users' subjective opinions related to the product quality, and there are no metrics provided for quantifying each quality factor objectively. Although SMI-Cloud proposes a set of metrics, some of the metrics are not quantifiable and the applicability of them are not provided. Besides, the metrics of important dimensions such as portability and transparency are not provided and they are not quantifiable. Furthermore, SMI-Cloud only targets IaaS providers in particular, not Cloud-EIS in general.

As a result, it is observed that existing quality models are mostly subjective and insufficient for the quality assessment of Cloud-EIS. Therefore, this study presents a comprehensive and well-structured quality model of Cloud-EIS that provides a systematic quality assessment for diagnosing the quality of Cloud-EIS products.

This study follows the steps listed in Table 1 in order to investigate the research questions of the study.

The remainder of this study is structured as follows. The literature review of the study and existing quality models; including software quality models, service quality models, and cloud-related quality models are provided in Chapter 2. This chapter highlights the weaknesses and powerful sides of each quality model. The analysis of existing quality models, and the development of the quality model of Cloud-EIS are presented in Chapter 3. In Chapter 4, identification of the quality metrics and the applicability of them are provided. In Chapter 5, the Analytic Hierarchy Process (AHP) method is employed in order to rank the quality factors of Cloud-EIS, and the findings of the AHP survey are presented. Finally, the conclusion of the study is stated.

Table 1: Research Steps

Phases	Explanation
Phase 1 (Chapter 2)	Literature review of the study
	Literature review on existing software and service quality models
	Detailed review on quality models related to Cloud Computing
Phase 2 (Chapter 3)	Building a database that records existing quality models and their quality dimensions
	Constructing a table tracing existing quality factors in the literature (See Table 2, and Table 3)
	Analyzing existing quality factors in order to identify the quality factors of Cloud-EIS (via group meetings with experts)
	Identification of a set of agreed-upon high-level quality factors of Cloud-EIS (via group meetings with experts)
	Decomposing each quality factor into subordinate quality factors (via group meetings with experts)
	Forming a comprehensive and hierarchically-structured quality model for Cloud-EIS
Phase 3 (Chapter 4)	Formulation of the metrics for each quality factor of Cloud-EIS
	Construction of the metrics table as consistent with the metric tables of the "ISO/IEC TR 9126-2 Software engineering –Product quality – Part 2: External metrics (2002)"
	Applicability of the proposed quality model of Cloud-EIS
	Comparison of three Cloud-EIS products
Phase 4 (Chapter 5)	Designing a survey based on AHP methodology that aims to rank (weighing) the quality factors of Cloud-EIS
	Distributing the survey amongst 35 experts consisting of PhD students and Experts from IT companies
	Finalizing the weights of the quality factor and their sub-quality factors
	Interpretation of the quality model of Cloud-EIS, according to the results of the AHP survey
	Comparison of the opinions between PhD students and Experts
Phase 5 (Chapter 6)	For the illustration of the quality assessment, two Cloud-EIS products, which are XAP Logistics and Shipping Management (2016) and SAP Business ByDesign Cloud ERP (2016) are selected.
	According to the metric values of these products provided in Chapter 4, and the weights of the quality factors obtained from the AHP survey as given in Chapter 5; Table 25, Table 26 and Table 27 are constructed.
	Table 28 is constructed, and Total Quality Index (TQI) of the products are calculated.

CHAPTER 2

LITERATURE REVIEW

In this section, a relevant literature review is presented. First of all, "cloud computing", "enterprise information systems" and "Cloud-EIS" are briefly explained. Consequently, software quality models and service quality models are reviewed in detail. Finally, existing cloud-related quality models are explained briefly.

2.1 Cloud Computing

With continuous advances in information technologies, a vast amount of computing power is required to gain competitive benefits and deep intuitive understanding of a business (Liu and Orban, 2008). Enterprises regularly process their data with operation power supplied by their private internal data centers. However, handling increasing data processing requests with a private data center could be complex and expensive. With the initiative, cloud computing appeals to most enterprises to implement cloud-based services based on a pay-as-you-go service model at a lower operating cost.

In the literature, there is no standard definition for "cloud computing" (Foster et al., 2008), (Sultan, 2010). Feuerlicht (2010) defines "cloud computing" as follows: "it involves the ability of the computing, data storage, and software services via the internet". Cisco (2009) states that cloud computing provides services on demand, at a reasonable price than the on-premise choices, with a lesser amount of complication, better scalability, and broader availability.

Referring the NIST definition (Mell and Grance, 2011), cloud computing is described as follows: "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., Networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction".

The cloud model consists of five essential characteristics, three service models, and four deployment models (Liu et al, 2011).

Essential characteristics of cloud models are *on-demand self-service, broad network access, resource pooling, rapid elasticity* and *measured service* (Liu et al., 2011).

According to the NIST model (Liu et al., 2011), cloud computing composed of three service models which are “Infrastructure as a Service (IaaS)”, “Platform as a Service (PaaS)” and “Software as a Service (SaaS)”. IaaS refers to the service capability to provision processing, storage, networks, and other essential computing resources to the customers. PaaS refers to installing infrastructure onto the cloud so that the clients can generate their own solutions or access applications provided on the cloud. SaaS allows clients to utilize many applications available on the cloud environment.

2.2 Enterprise Information Systems

EIS refers to any kind of information systems that improve business operations by the integration of the functions of an enterprise. EIS offers a platform that enables enterprises to integrate and manage their business operations on a robust basis. Enterprises implement various EIS such as CRM, SCM, and ERP, because of their advantages, such as processing large volume of data, handling complicated enterprise operations, and refining business quality.

ERP, provides integrated functional modules as a software package such as “production”, “sales”, “finance”, and “human resources”, is modifiable to the explicit requirements of prospective client organizations. According to Botta-Genoulaz and Millet (2006), the usage of ERP is increasing, due to benefits its competitive benefits, such as decreasing executive workload, reporting operations at a higher speed, handling real-time data, having more accurate data for enterprise resource planning as a result of integrating data from purchasing and accounting departments.

CRM is another kind of EIS, provides a system that supports building sustainable and improved relationship with customers. CRM is commonly employed by organizations to construct more reliable and strong interactions with customers and to advance their businesses (Suresh, 2004).

SCM is decribed as “the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for all stakeholders” (Lambet et al., 1998). SCM provides many advantages to organizations such as reducing stock cost, responding customer needs with shorter “lead times” and “replenishment” through more powerful cooperation with dealers or providers(Daghfous and Barkhi, 2009).

2.3 Cloud-EIS

Up to now, there is no common description of Cloud-EIS. Cloud-EIS enables EIS to be provided through the Internet and available to numerous clients at reasonable prices, through the flexibility and capability of Cloud Computing (Liu et al, 2011). As a result, it can be defined as a flexible, yet robust information system integrated with Cloud Computing, which enables enterprises to offer increasing levels of flexibility and agility. Unlike traditional EIS, Cloud-EIS enable users to access many services provided by the cloud provider via network connection, and to purchase only relevant function modules based on a pay-as-you-go basis without purchasing the whole EIS (Sharif, 2010). According to Nedbal et. al., 2014, Cloud-EIS is the fastest way to implement cutting edge EIS, and also an economical way to allow multiple clients to access the same virtual resource by eliminating “upgrading server” or expenditure on equipments. Most firms have started to implement Cloud-EIS solutions to solve various problems encountered in the regular on-premise EIS (De Loo et. al., 2011). According to Beaubouef (2016), Cloud-EIS is a world-shattering transformation model for innovative organizations, especially for new startups that could not meet the expenses of the sophisticated IT systems.

2.4 Quality and Its Impacts on Business Performance

Since the term of “quality” is subjective and perceptual, there is no standard definition available in the literature. Referring to American Society for Quality (ASQ), it can be concluded that quality is not an objective term. Therefore, each individual or sector can form its own specific descriptions.

Juran (1979) states the definition of quality as ““Fitness for use”, while Parasuraman et al. (1988) defines the quality as “Meeting and/or exceeding the customer expectations”.

IEEE standard (IEEE Std 729-1983) defines this term as follows: “The totality of features and characteristics of a software product that bear on its ability to satisfy given needs: for example, conform to specifications”.

Researchers suggest that business performance is affected by the quality. Capon et al. (1990) prove that positive correlation between quality and business performance by conducting a meta-analysis of 20 studies. Therefore, enterprises should assign priority to the assessment of quality in all aspects of their businesses. For this aim, enterprises look for an appropriate quality assessment method for evaluating and improving their quality levels to have competitive advantages such as increasing market share and profits, improving the efficiency of business operations, decreasing the cost of operations etc.

Enterprises from all sectors, especially large-size organizations perceive the significance of the product and service quality. Consequently, they assign high priority to the quality in order to increase the quality level of their products and services, in that way they can boost the brand reputation, and appeal more customers.

2.5 Software Quality Models

Referring to the “IEEE Standard Glossary of Software Engineering Terminology (1990)”, definition of the software quality is stated as “the degree to which a system, system, component, or process meets specified requirements”, or “the degree to which a system, system component, or process meets customer or user needs or expectations”.

The ISO standard offers international standards for product and process quality. While “ISO/IEC JTC1, ISO-15504-5 (2004)” is related to software process quality, “ISO/IEC JTC1 ISO9126 (1-5) (2001)” is about the software product quality.

As for software process quality, there are many studies that employ CMM (Capability Maturity Model) to evaluate software process quality. Duarte and Silva (2013) employed CMM for cloud-based services and offered a guideline for cloud adoption and management (Duarte and Silva, 2013).

The product quality of software refers to the software quality model. Since the software quality framework is defined as, "a set of characteristics and sub-characteristics, as well as the relationships between them that provide the basis for specifying quality requirements and evaluating quality" (Beus-Dukic and Boegh, 2003), it is a suitable instrument to evaluate the software quality.

Characteristics: It is described as the top level features of a system that represents main perspectives of quality. For example, according to the ISO 9126 model, portability, and efficiency are characteristics of the quality.

Sub-Characteristic: It refers to components of the main characteristics. For instance, time, behavior and resource behavior are sub-characteristics of the characteristic of "efficiency".

Quality Attribute: It represents precise explanations for each characteristic or its sub-characteristics that offer proof for or against the presence of an explicit quality factor. For instance, "response time of the corresponding software" is a quality attribute under the sub-characteristic of "time behavior".

Quality Measures: It qualifies the attributes of the quality model. Hence, attributes of the quality framework can be quantifiable, non-subjective and unambiguous. For example, the time between service request and service access is the measure of the attribute of "response time".

2.6 Review of Software Quality Models

There is no standard and commonly accepted pattern for evaluating the software quality. The researchers have attempted to define a quality framework for software product quality since 1976. There are many different quality models which have been proposed by several researchers.

In this section, most prominent and widely accepted software quality models are described. In addition, powerful and weak aspects of each quality model are highlighted.

2.6.1 *McCall's Model*

McCall's Model was developed in 1976 by the "US air-force Electronic System Decision (ESD), Rome Air Development Center (RADC), and General Electric (GE)", with the purpose of refining the software quality (Fitzpatrick, 1996).

McCall's software quality model consists of eleven factors related to three aspects of the software, which are "product operations, product revisions, and product transitions" (McCall et al., 1977). Product operation refers to the product's ability to be easily understood and efficiently functioned, and the capability of offering the outcomes requested by the user. This aspect covers product characteristics as follows: "modifiability, reliability, efficiency, integrity, usability". Product revision refers to "error correction and system adaptation", and it includes "maintainability, flexibility, and testability". Product transition is related to distributed processing among varying hardware, and this aspect has following product characteristics Portability, Reusability, and Interoperability.

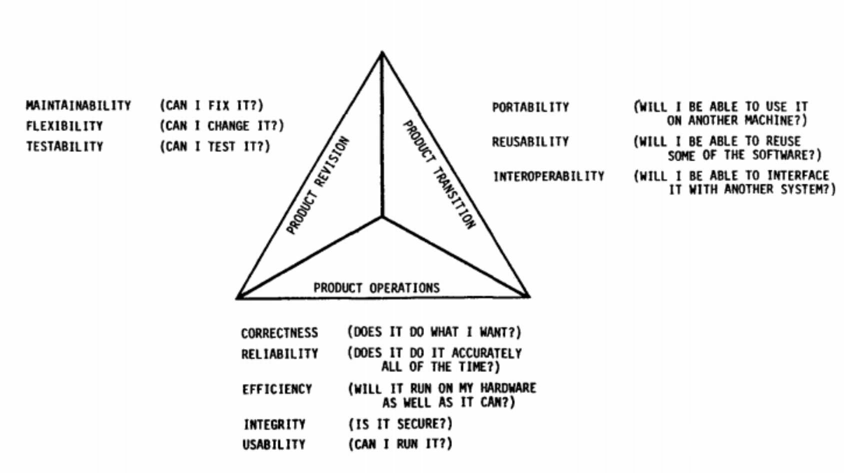

Figure 1: McCall Quality Framework (1997)

As seen from Figure 1, McCall model offers eleven software quality factors under three aspects of the software quality.

The main powerful contribution of McCall Model is the connection formed between quality factors and metrics. Although it is discussed that not all metrics are objective, this model provides a generic framework to assess software quality. However, this model does not clearly consider the functionality of the software product as a quality factor.

2.6.2 *Boehm Model*

This quality model is developed in 1978 (Boehm et al., 1978), and much more similar to McCall model. The Boehm model highlights the maintainability of the product. This model covers the software quality factors as follows: "portability, utility, maintainability, reliability, efficiency, human engineering, testability, understandability, and modifiability". This framework also embraces concerns related to the assessment of software in regard to the utility of the software package. As similar to McCall model, it presents a hierarchical form of quality characteristics, each of them affects the overall quality. Boehm model has a wider range and includes 19 criteria. Beside the quality characteristics related to user's needs, these criteria also cover quality characteristics of hardware performance that are missing in the McCall model (Kececi ve Abran, 2001). However, the Boehm model proposes only a hierarchical diagram of characteristics without any recommendation about measuring them.

2.6.3 *FURPS Model*

The FURPS model is proposed by “Robert Grady and Hewlett-Packard Co.” (Khosravi and Gueheneuc, 2004). It classifies characteristics into two groups of requirements as follows:

Functional requirements (F): Defined by input and expected output.

Nonfunctional requirements (URPS): Usability, reliability, performance, supportability.

One weakness of the FURPS model is that it does not consider the software product’s portability.

2.6.4 *Dromey Model*

Dromey model investigates to the relation between characteristics and sub-characteristics of the software quality (Dromey, 1995). The model incorporates with a two-level hierarchy which consists of high-level attributes and subordinate attributes. Dromey points out that the assessment of each product is not same and a more dynamic framework is required. The key notion is to create a model that can be applied to a wide range of different software.

The weak side of the model is that it has a lack of criteria for the measurement of software quality.

2.6.5 *BBN Model*

BBN Model is defined as “The Bayesian belief network (BBN) is a kind of graphical models, where the nodes embody variables and the directed arrows embody the relation between the variables” (Stefani et al., 2003), (Stefani et al., 2004). According to BBN model, the quality framework can be depicted as a hierarchical structure, and the root of the tree stands for Quality and it is linked to quality characteristic nodes. Moreover, each node is linked to related sub-characteristics.

BBN model is suitable for complex quality assessment. However, this model suffers from the lack of criteria to evaluate software quality.

2.6.6 *Star Model*

Star Model is categorized a conceptual framework that covers different aspects of the software quality (Khosravi & Guéhéneuc, 2004). Despite considering different perspectives on the quality, just as BBN model, it has a lack of the criteria.

2.6.7 *ISO Model*

There are many software quality models in the literature, yet none of them is standardized. Thus, the need of the standard software quality model has emerged. The ISO/IEC JTC1 initiates and encourages the standardization. Initial concerns date back in 1978 and the development of the “ISO/IEC 9126” initiliazed in 1985.

The ISO/IEC JTC1 has tried to reach a consensus on the standard software quality model. Initial researched was started in 1978, and the development of the "ISO/IEC 9126" begun in 1985.

The ISO 9126 (2001) is a part of the "ISO 9000 Quality Assurance Standard". This model classifies software quality factors in a hierarchical tree structure. The top level of the structure consists of the quality characteristics and their sub-characteristics, and the lowest level of the hierarchy involves the software quality criteria. As seen from Figure 2, the model proposes six characteristics as follows: "Functionality, Reliability, Usability, Efficiency, Maintainability, and Portability". Besides, the total number of the sub-characteristics is equal to 21.

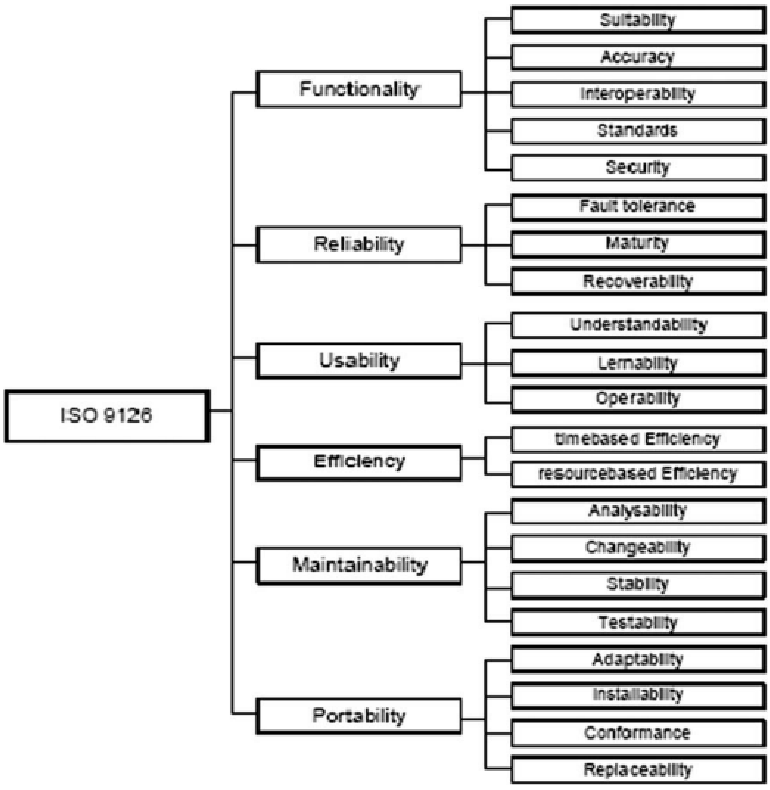

Figure 2: "ISO 9126 Software Quality Characteristics" (2001)

The characteristics of the "ISO 9126" are identified in a way that is applicable to all sorts of software, including software packages and data enclosed in firmware. Furthermore, it offers coherent terminology related to the quality of the software. Consequently, the ISO 9126 offers a quality framework that can be applied to conduct trade-off analysis, among the software products (ISO/IEC 9126-1, 2001).

It can be concluded that the ISO software quality model is more comprehensive and generic and powerful than other models. The main prominent features of the ISO quality framework are as follows: having standard terminology for software quality, together with easily understandable and precise descriptions; hierarchical layers with criteria for assessment of the quality of the software product. Thus, the ISO model forms the significant part of the proposed research model for evaluating cloud-based EIS.

2.6.8 *Other Software Quality Models*

In this section, the most cited quality models which are developed based on the " ISO/IEC 9126 (2001)" are reviewed. The dimensions of all reviewed models are given in a table in Chapter 3.

The quality models proposed based on the "ISO/IEC 9126" are as follows:

- Sharma et al. (2008) proposed a quality model from the aspects of Component-Based Software Development. They added trackability, complexity, reusability, and flexibility to existing the ISO/IEC 9216 model. They applied the "Analytical Hierarchy Process (AHP)" to prioritize and calculate the weight of each characteristic.
- Chang et al (2008) also developed a quality model based on the ISO/IEC 9126. They applied the Fuzzy AHP to obtain the weights of the characteristics and their sub-characteristics.
- Rawesdah (2006) developed a model based on "commercial off the shelf components". They excluded following sub-characteristics from the ISO-9126: "fault tolerance, configurability, scalability, and reusability model". They proposed a new characteristic called "maintainability". Furthermore, the model considers only external metrics. Thus, the limitation of the study is that it cannot measure internal features of a software quality.
- Alvaro et al (2005) involved some sub-characteristics as follows: self-contained, configurability, scalability, and reusability. Some sub-characteristics of the "ISO/IEC 9126 model" such as maintainability were excluded. They defined component based quality framework and a set of metrics for evaluation.

2.7 Review of Service Quality Models

In this section, existing service quality models are briefly explained.

2.7.1 *Servqual*

Servqual is proposed by Parasuraman et al. (1985; 1988) as an instrument that measures the service quality. It mainly relies on questioning customers' expectations and/or their opinion related the service delivered. Then the service quality is identified as a level of what extent the service provided meets the customer requirements.

In literature, the definition of the "service quality" stated by Lewis and Booms (1983) inspire many researchers to develop a quality framework. From one of these researchers, Grönroos (1984) builds up the service quality model. Grönroos (1984) suppose that "technical" and "functional" measurements that identify the gap between anticipated service and received service. Parasuraman et al. (1985; 1988) proposed SERVQUAL as a tool to assess the service quality as stated above. According to this framework, there are five dimensions as follows: " Tangibles, Reliability, Responsiveness, Assurance, Empathy".

Researchers employ The Servqual to measure service quality in various sectors such as healthcare industry, banking, accounting, etc. (Parasuraman, 1995).

2.7.2 *Webqual*

Webqual 1.0 initially was developed by Loiacono et al. (2002) to measure the quality of websites by employing Quality Function Deployment (QFD). They proposed 12 dimensions which are: "informational fit-to-task, tailored communications, trust, response time, ease of understanding, intuitive operations, visual appeal, innovativeness, emotional appeal, consistent image, on-line completeness, and relative advantage". However, researchers find out that there is a missing part of evaluating web-quality, which is "interaction quality". Interaction quality is defined as "a period of time during which a consumer directly interacts with a service" (Solomon et al., 1985).

After extensive examination of Webqual 1.0, and following the principle of The Servqual, the Webqual 2.0 is developed by Zeithaml et al. (1990). The dimensions of webqual 2.0 as follows: " Aesthetics, Navigation, Reliability, Competence, Responsiveness, Access, Credibility, Security, Communication, Empathy".

Since Webqual is commonly employed by researchers to evaluate e-commerce website quality. E-qual is another service quality model that is developed based on Webqual.

2.7.3 *Information Systems Success Model*

Information Systems (IS) Success Model is developed in 1992 (DeLone & McLean, 1992). Since the measurement of the IS success is significant for the decision of IS investments and there is a need for an all-inclusive model that can evaluate the success or productivity (DeLone & McLean, 2003), this model forms the concept of IS success. Thereby the researchers are able to study IS success based on this model.

In 2003, Updated IS Success Model is proposed (DeLone and McLean, 2003). According to Updated IS Success Model, e-commerce success metrics are developed. However, this model does not contribute to developing a quality model of Cloud-EIS. Therefore, it is out of the scope of this study.

2.8 Review of Cloud-related Quality Models

In this part, existing cloud-related quality models are reviewed. SMI-Cloud, SaaS-Qual, Cloud-Qual, ASP-Qual are proposed to evaluate cloud-based services or products.

2.8.1 *SMI-Cloud*

The Cloud Service Measurement Index Consortium (CSMIC) defined measurement indexes which are provided as Service Measurement Index (SMI). Garg et al. (2011) developed SMI-Cloud based on the indexes of SMI. The SMI-Cloud is proposed as a comparison tool of cloud providers. The constructs of this model are mainly derived from the ISO 9126 Software Quality Model(1998), which are stated as follows:

"accountability, agility, assurance of service, cost, performance, security and privacy, and usability". The authors proposed a set of metrics as Key Performance Indicators (KPI) that measure the quality of cloud providers. The case study provided in SMI-Cloud quality model is related to the assessment of three IaaS cloud providers selected (i.e., Amazon EC2, Windows Azure, and Rackspace). They are evaluated by using the metrics proposed.

2.8.2 *SaaS-Qual*

SaaS-Qual is developed based on the Servqual model by Benlian et al. (2011) in order to evaluate the quality of SaaS. They conducted interviews with enterprises, and a card-sorting method in order to develop the SaaS-Qual which is a quality framework for SaaS applications.

Since it is developed based on the Servqual, it consists of the Servqual quality dimensions which are assurance, empathy responsiveness, reliability, and features. The authors also identified two cloud-specific quality factors (i.e., Security and flexibility) which are essential for the assessment of the SaaS service quality. As a consequence of the field interview, they merged two factors (i.e., Assurance and empathy) into one single factor which is called rapport. As a result, they proposed the quality model of SaaS applications.

2.8.3 *Cloud-Qual*

Cloud-Qual model is proposed by Zheng et al. (2013) with the aim of providing Quality of Service (QoS) negotiation for the consumers of cloud-based solutions. This model is mainly influenced by the Servqual, and other e-qual quality models such as SMI-Cloud. This quality framework proposed six dimensions and their metrics. Usability, availability, reliability, responsiveness, security, and elasticity are proposed as dimensions and the metrics of them are used by a case study of the benchmarking of three cloud-based storages which are Amazon S3, Azure Blob, and Aliyun OSS. Thus, this study also provides a tradeoff negotiation approach for assessment of cloud providers.

2.8.4 *ASP-Qual*

Application Service Provider (ASP) is defined as "any third party organization whose main business is providing software-based services to customers over a wide area network in return for payment" (Smith and Kumar, 2004). These applications can be a kind of enterprise solutions such as SCM, ERP or domain specific software provided by a third party organization. ASP-Qual is proposed by Ma et al. (2005) as a quality framework for the assessment of ASPs. This model is constructed based on the dimensions of the Product Quality Model (Garvin, 1987) and the dimensions of the Servqual (Parasuraman et al., 1995). The quality factors in the model are identified by the combination of quality dimension of these two models, and the quality factors are proposed as follows: features, reliability, availability, assurance, empathy, conformance and security.

CHAPTER 3

DEVELOPING A QUALITY MODEL FOR CLOUD-EIS

In this chapter, the analysis of the existing quality models and the development of a quality model for Cloud-EIS are stated.

3.1 Analysis of Existing Quality Model

As stated Chapter 2, existing quality models including software quality models, service quality models, and cloud-related quality models are reviewed. In order to address the quality of Cloud-EIS, Table 2 and Table 3 are constructed for tracing available quality factors and their total number of occurrences in different quality models.

The following operations are applied while listing existing quality factors in the table:

- The definition of each quality factor is analyzed. The factors which have same meanings are merged. For example, “application features” of ASP-Qual has the same definition with “functionality” of the ISO 9126 Model. The factors of “personalization” and “customization” are merged as well.
- “Trust” and “Assurance” and “Transparency”; “Web appearance” and “Site aesthetics”; “Compliance” and “Compatibility” are merged as well.
- “Elasticity” and “Scalability” and “Flexibility” are merged into one single factor which is called “Elasticity”.
- “Complexity” and “Ease of Use” are also merged, since they have same research questions in terms of the assessment of the difficulty level of the product.

Table 2: Tracing Quality Factors in the Existing Models (Part 1)

	Main Quality Model						Enhanced Quality Model (based on one of the Main QM)											
Quality Factors	McCall Model	FURPs Model	ISO/IEC 9126	Servqual	E-Service Qual	Webqual	SMI-Cloud	ASP Qual	Saas Qual	Cloud-Qual	Behshid Behkamal et al. (2008)	A. Rawasdeh et al. (2006)	A. Alvaro et al.(2010)	J. Yahaya et al(2010)	Avadhesh Kumar et al. (2009)	Ioannis Samoladas et al(2008)	Bartoa et al. (2003)	Total
Functionality		x	x			x	x	x			x	x	x	x	x		x	11
Reliability			x	x	x	x	x	x	x	x	x	x	x	x	x		x	14
Usability	x		x			x	x			x	x	x	x	x	x		x	10
Efficiency	x		x		x	x					x	x	x	x	x	x	x	11
Maintainability	x	x	x								x	x	x	x	x	x	x	10
Portability	x	x	x								x		x	x	x			7
Empathy				x		x		x										3
Tangibles				x		x		x										3
Responsiveness				x	x	x	x	x	x	x							x	8
Trust				x	x		x	x										4
Ease of navigation					x	x												2
Information Accuracy		x	x			x	x				x		x	x	x		x	9
Web apperance		x			x	x					x							4
Sustainability							x											1
Suitability			x				x				x	x	x	x	x		x	8
Interoperability	x		x				x				x	x	x	x	x		x	9
Stability			x				x				x		x		x	x		6
Cost					x		x										x	3
Customization		x	x		x		x				x		x	x	x			8
Elasticity	x				x		x	x	x	x			x		x			8
Security		x	x		x			x	x	x	x			x	x	x		10
Access					x													1
Availability								x		x								2
Rapport									x									1

Table 3: Tracing Quality Factors in the Existing Models (Part 2)

	Main Quality Model						Enhanced Quality Model (based on one of the Main QM)											
Quality Factors	**McCall Model**	**FURPs Model**	**ISO/IEC 9126**	**Servqual**	**E-Service Qual**	**Webqual**	**SMI-Cloud**	**ASP Qual**	**Saas Qual**	**Cloud-Qual**	**Behshid Behkamal et al. (2008)**	**A. Rawasdeh et al. (2006)**	**A. Alvaro et al.(2010)**	**J. Yahaya et al(2010)**	**Avadhesh Kumar et al. (2009)**	**Ioannis Samoladas et al(2008)**	**Bartoa et al. (2003)**	**Total**
Compliance		x	x								x	x					x	5
Maturity			x								x	x	x	x	x	x	x	8
Fault Tolerance			x								x		x	x	x			5
Recoverability		x	x															2
Understandability			x								x	x	x	x	x		x	7
Learnability			x								x	x	x	x	x		x	7
Operability			x								x	x	x	x	x		x	7
Time Behavior			x								x	x	x	x	x		x	7
Resource Behavior			x								x	x	x	x	x		x	7
Analyzability			x								x			x	x	x	x	6
Changeability			x								x	x	x	x	x	x		7
Testability	x	x	x								x	x	x	x	x	x	x	10
Installabiltiy			x														x	2
Co- Existence			x											x	x			3
Replace ability			x								x		x	x	x			5
Complexity						x		x			x	x			x		x	6
Reusability	x												x		x			3
Configurability		x											x					2

As seen from Table 2 and Table 3, reliability is the most common quality factor that shows its presence in 14 models out of 17 quality models. While functionality, usability, and efficiency appear in 11quality models; maintainability, security, and testability are placed in 10 models from 17 models. Information accuracy, interoperability, maturity, elasticity, customization, and suitability appear in between 8-9 models out of 17 quality models.

As a conclusion, the “ISO 9126 Software Quality Model” is found as the most generic quality model that can be modified to any specific context. Furthermore, it has many powerful features as follows: having standard terminology for product quality; providing easily understandable and precise descriptions of quality factors; offering hierarchical layers of quality factors for systematic assessment. While a newer standard entitled as “ISO/IEC 25010:2011Systems and Software Engineering: Systems and Software Quality Requirements and Evaluation (SQuaRE)”, which is an extension of the ISO 9126 standard, is available, the dimensions of ISO 9126 are more widely referred to and utilized in the literature related to the domain of interest. Accordingly, the ISO 9126 Software Quality Model forms the basis of the quality model of Cloud-EIS.

3.2 Detailed Analysis of Cloud-related Quality Models

Servqual is proposed to assess service quality through the evaluation of customer perception of quality and satisfaction toward the service provided. However, this model is criticized by many researchers because of having difficulties of applying the Servqual dimensions (Brown et al., 1993; Parasuraman et al., 1993; Peter et al., 1993). Secondly, all quality dimensions of the Servqual are subjective; not objective (Benlian et al., 2011). Furthermore, there are no cloud-specific dimensions such as elasticity, the performance of cloud service. Because of these reasons, it cannot be employed to measure the quality of Cloud-EIS without any modification.

Upon conducting a literature review, it is concluded that there is a need for a quality model dedicated to Cloud-based services. Ferretti, et al. (2010) developed a middleware in order to respond to customer needs efficiently. However, they only consider response time and availability as quality dimensions. Reliability, security and privacy issues are not enclosed the model. Alhamad, Dillon and Chang (2010) proposed an SLA framework for Cloud-based services, but it has no quality metrics. Furthermore, a quality framework proposed in order to evaluate service quality of SaaS applications (Benlian et al., 2011). However, the model only focuses on SaaS applications, not on cloud-based enterprise solutions in general. SMI-Cloud is another quality model which is developed to evaluate IaaS service quality based on Service Measurement Index (SMI) of cloud providers and to help customers select a suitable cloud provider (Garg et al., 2011). Although this model identifies quality factors and the corresponding metrics, some of the significant quality factors (e.g., portability, maintainability) are disregarded. Besides, it only focuses on IaaS service model, not on Cloud-EIS specifically.

As a result, there are many models which are intended to evaluate Cloud-based services; but none of them is dedicated to Cloud-EIS such as Cloud-ERP, Cloud-

CRM, Cloud-SCM, etc. Secondly, the existing models only consider The Servqual model as a baseline of quality models being developed. Since Cloud-EISs cover a wide range of services including PaaS, SaaS, and IaaS service models, the quality of Cloud-EIS depends on not only the quality of service provided over the Internet, but also the quality of the software itself. Consequently, existing cloud-related quality models are reviewed. Accordingly, the following Table 4 is constructed in order to have insight on identifying cloud-specific dimensions of the proposed quality model of Cloud-EIS.

Table 4: Review of Quality Models of Cloud Computing

Quality model	**Factors**	**Baseline study of the model**	**Research context**	**Criticism**
SMI-Cloud	"Accountability, agility, assurance of service, cost, performance, security& privacy, and usability"	It relies on the attributes proposed by the "Cloud Service Measurement Index Consortium (CSMIC)"	IaaS Quality	Cost is considered as a quality parameter. There is obviously a correlation between cost and quality. But, the quality of the product should be assessed independently from the cost of the service. Some metrics are non-quantifiable and important metrics such as portability and transparency metrics are missing. As Zheng et al. (2013) stated, the quality dimensions suffer from lack of justifications, and important quality dimensions are missing. Furthermore, it only targets IaaS quality.
SaaS-Qual	"Rapport (assurance& empathy), responsiveness, reliability, and features (functionality)"	Servqual	SaaS-CRM Quality	The quality model relies on survey responders' subjective opinion related to the product. Thus, the measurement of the quality is subjective, not objective. No metrics provided for quantifying the quality factors of the model. Besides, It only targets SaaS-CRM quality.
Cloud-Qual	"Usability, availability, reliability, responsiveness, security, and elasticity"	Servqual, other modified service quality model such as e-qual and Webqual	Cloud Services Quality- but case study only for IaaS	Although the quality framework is proposed to evaluate cloud services (IaaS, PaaS, SaaS), an empirical case study of the study only evaluates cloud-based storage solutions (IaaS). Besides, security and reliability dimensions appear to be not well-quantifiable. Definition of the security dimension seems to be general, not for cloud services in particular.
ASP-Qual	"Features, reliability, availability, assurance, empathy,	Servqual and Product quality model	Cloud Providers	As Benlian et al. (2011) stated, the dimensions are subjective, not objective. There are no metrics measuring the quality. It relies on the subjective opinion of the survey

	conformance, security"			responders.

As seen from the table, there is no quality model for cloud-based enterprise solutions such as Cloud-SCM, Cloud-ERP or Cloud-CRM. Although SaaS-Qual proposes a quality model for Cloud-CRM, the quality model relies on survey responders' subjective opinion related to the product. Since SaaS-Qual does not provide any metrics that measure the quality of Cloud-CRM objectively, the measurements of all quality dimensions are subjective, not objective. However, the SMI-Cloud proposes a set of metrics, yet some of the metrics are not well-quantifiable. As Zheng et al. (2013) stated, the quality dimensions suffer from lack of justifications. Besides, the metrics of important dimensions such as security, portability, and transparency are not provided. Furthermore, the SMI-Cloud only targets IaaS providers in particular, not Cloud-EIS in general.

Additionally, existing cloud-related quality models only consider service quality models as a baseline of their study. None of them consider software quality models for the assessment of IT features of Cloud-based services. Therefore, this study develops a quality model for Cloud-EIS that considers both service quality and software quality, and provides objectively quantifiable metrics for the systematic assessment of the product quality.

3.3 Developing a Quality Model for Cloud-EIS

As seen from Figure 3, first of all, the quality factors of Cloud-EIS are identified from the literature. Consequently, each quality factor is divided into sub-quality factors. This section presents the explanation of these two steps. Formalization of the metrics is provided in Chapter 4.

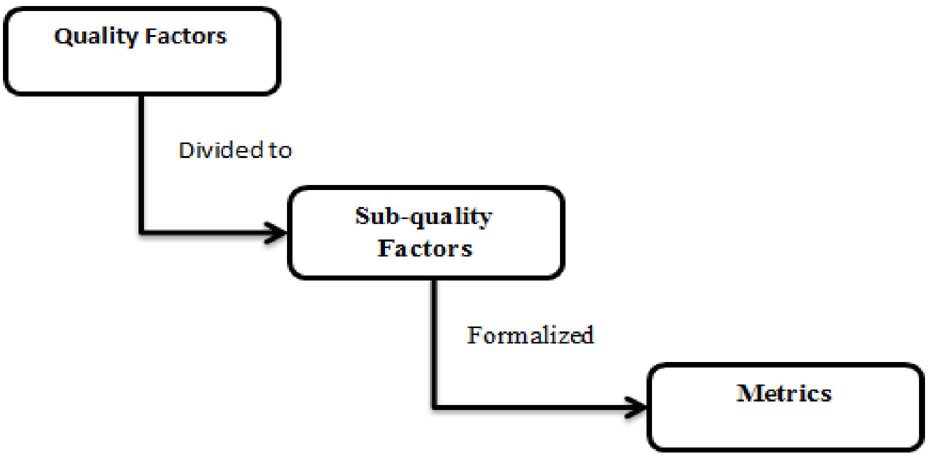

Figure 3: Developing a Quality Model for Cloud-EIS

In order to address the quality measurement of Cloud-EIS products, a quality model is developed after analyzing the existing quality models, standards related to security and privacy issues of cloud computing, and the NIST document of cloud computing services (Liu et al, 2011).

- As stated in Chapter 2, the ISO 9126 Software Quality Model is found as the most comprehensive, powerful and generic software quality model amongst the other existing software quality models and it is almost free of shortcomings for evaluating software quality. However, it still needs modification and extension for evaluating Cloud services. Therefore, ISO 9126 is considered as a baseline for the assessment of software quality of Cloud-EIS.
- The existing service quality models such as Servqual and Webqual are reviewed and considered as influencing quality models for the assessment service quality of Cloud-EIS.
- ISO 270017 Security Issues for Cloud Services (2015) and ISO 270018 Privacy Issues for Cloud Services (2014), providing security and privacy techniques for cloud services are analyzed in detail. Consequently, the quality factor of “Security and Privacy” is developed.
- Referring to the document of “NIST Cloud Computing Reference Architecture” (Liu et al, 2011), cloud-specific quality dimensions such as Elasticity, Ease of Access are developed.

Since the quality model of Cloud-EIS incorporates software quality and service quality together, the following steps are applied in order to build an integrated quality model for Cloud-EIS.

Upon literature review of software quality models and analyzing ISO 270017 Security Issues for Cloud Services and ISO 270018 Privacy Issues for Cloud Services and the cloud computing characteristics stated in the NIST the following modifications are applied to ISO 9126 Software Quality Model in order to build the software quality part of the model for Cloud-EIS:

- “Ease of Access” is added as a sub-factor of functionality. Since one of the cloud computing characteristic is broad network access to cloud services, the quality of the access should be quantified for Cloud-EIS product.
- Security is removed from the sub-quality factors of functionality. Upon analyzing definition “security” and its metrics provided in the ISO 9126-External Metrics (2002), it is concluded that this factor only considers the issue of unauthorized access as a security problem of software. Since the security and privacy level of Cloud-EIS is a significant quality factor that affects enterprises regarding the decision of moving to the cloud, it should be comprehensive and well-structured in order to qualify or measure the security and privacy level of Cloud-EIS products. As Dhamdhere (2014) stated that cloud-based systems still need to explain security necessities such as integrity, confidentiality, audit, monitoring, and security incident management, a new quality factor called “Security & Privacy” is proposed. Accordingly, the sub-quality factors of Security & Privacy are developed as well.
- Compliance is removed from the sub-quality factors of functionality. Since compliance of the software is a significant quality factor, it should be main quality factor. Therefore, “Policy and Regulation” is proposed as a main quality factor of Cloud-EIS. This factor qualifies the level of compliance with

standards, conventions, international laws, contracts or other regulatory requirements.

- Cloud-specific Customization metric is proposed in addition to metrics of “customizability” in the ISO 9126 Standard. Since the ability of modification of cloud services according to enterprise/individual preference is found as a significant quality factor that affects the decision of selecting the suitable Cloud-EIS product, customization metric is defined as the number of APIs available for customization operation in the software.
- Since the availability of cloud-based application is a significant factor in order to sustain specified service level of cloud products, “Availability” is defined as system uptime and proposed as a sub-factor of Reliability.
- “Open Source Availability” is found as a significant factor for maintenance of cloud services with respect to software improvement, adjustment or adaptation to the changes, etc. Therefore, it is proposed as a sub-factor of Maintainability.

Having extensive literature on service quality models and analyzing cloud computing characteristics stated in the NIST, the following quality factors are developed in order to build the service quality part of the model for Cloud-EIS:

- “Elasticity” is proposed as the main quality factor of Cloud-EIS. Since elasticity is one of the major characteristics of cloud computing services, it should be considered for assessment of cloud service quality. Therefore, it is developed to measure the elasticity of cloud services.
- Customer Service Quality is developed to qualify the level of quality of providers’ customer service.

As a result, the quality model of Cloud-EIS is constructed as a comprehensive and a hierarchically-structured, consisting of 10 main quality factors and their sub-quality factors as seen from Figure 4.

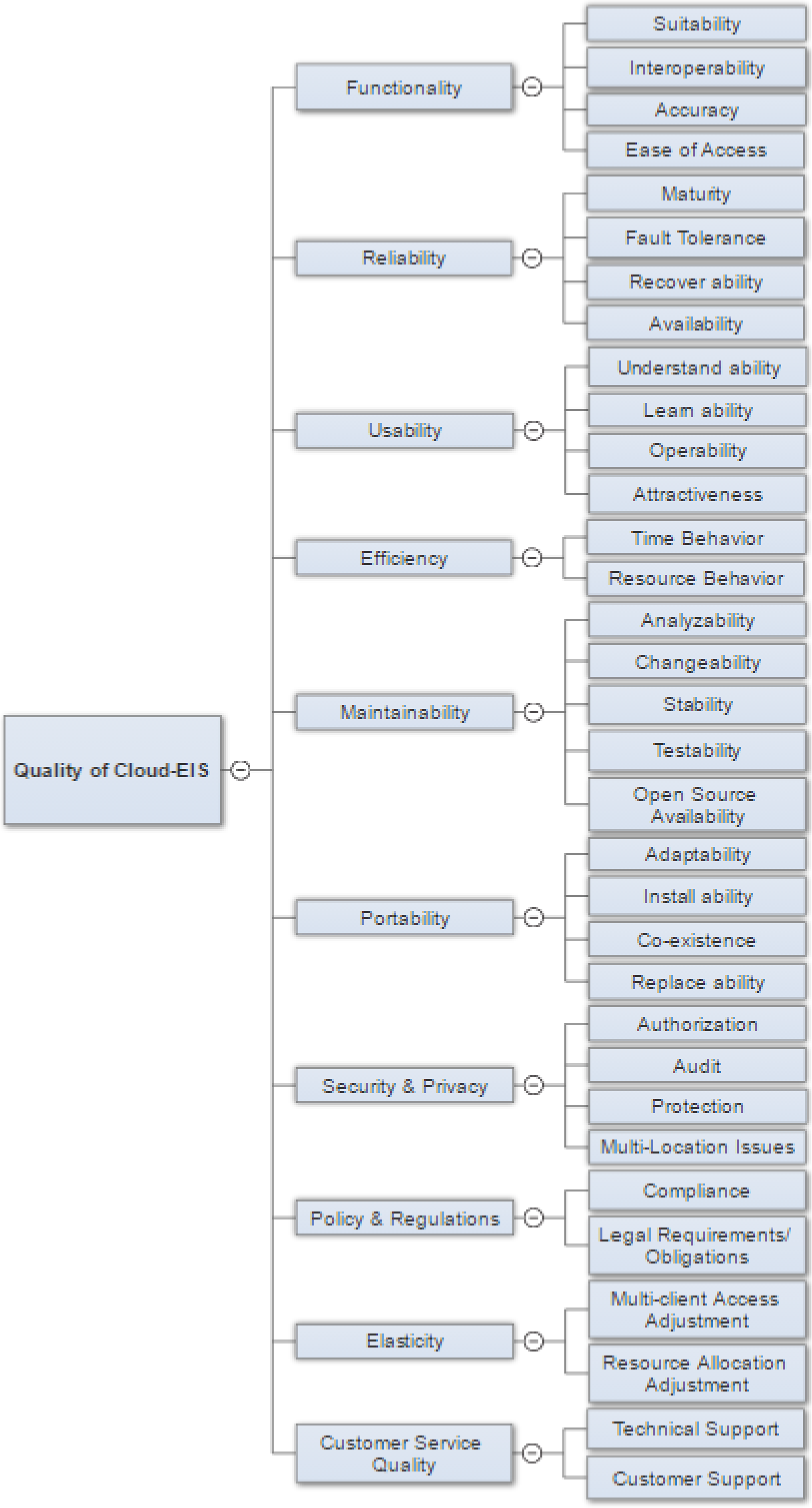

Figure 4: The Proposed Quality Model of Cloud-EIS

3.3.1 *Definitions of the Quality Factors*

Since some of the main quality factors of Cloud-EIS are derived from the "ISO 9126 Quality Model-1 (2001)", the definitions of them are reproduced from the "ISO/IEC

9126(1998)". The definitions of the quality factors of the "ISO 9126 Software Quality Model (2001)" are given as seen from Table 5.

Table 5: Quality Factors of the "ISO 9126 Model" (Losavio et al, 2004)

Quality factors	Definitions
Functionality	The capability of the software to provide functions which meet the stated and implied needs of users under specified conditions of usage (what the software does to meet needs).
Reliability	The capability of the software product to maintain its level of performance under stated conditions for a stated period of time.
Usability	The capability of the software product to be understood, learned, used and provide visual appeal, under specified conditions of usage (the effort needed to use).
Efficiency	The capability of the software product to provide desired performance, relative to the amount of resources used, under stated conditions
Maintainability	The capability of the software product to be modified. Modifications may include corrections, improvements or adaptations of the software to changes in the environment and in the requirements and functional specifications (the effort needed to be modified)
Portability	The capability of the software product to be transferred from one environment to another. The environment may include organizational, hardware or software environment

In addition to the quality factors of the "ISO 9126 Software Quality Model (2001)", the following main quality factors of Cloud-EIS are proposed as listed in Table 6.

Table 6: Definitions of the Proposed Quality Factors of Cloud-EIS

Quality Factors	Definitions
Elasticity	According to NIST (2011) definition, "Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in."
Security& Privacy	It covers confidentiality (unauthorized revelation of data), integrity (unauthorized operation and destroying data), audit, protection, and multi-location issues.
Policy& Regulations	It quantifies the level of compliance with standards, conventions, contracts or other regulatory requirements.
Customer Service Quality	It quantifies the level of the quality of Cloud-EIS provider's customer service.

Since some of the sub-quality factors are derived from the "ISO 9126 Quality Model-1", the definitions of them are reproduced from the "ISO/IEC 9126 Software Product

Evaluation - Quality Characteristics and Guidelines for the User (2001)" as seen from Table 7.

Table 7: Sub-quality factors of the "ISO/IEC 9126 Software Quality Model (2001)"

Quality Factors	**Sub-quality factors**	**Definitions**
Functionality	Suitability	The appropriateness (to specification) of the functions of the software
	Interoperability	The ability of a software component to interact with other components or systems
	Accurateness	The correctness of the functions, providing correct function result
Reliability	Maturity	The frequency of failure of the software
	Fault tolerance	The ability of software to withstand (and recover) from component, or environmental, failure
	Recoverability	Ability to bring back a failed system to full operation, including data and network connections.
Usability	Understandability	The ease of which the system functions can be understood
	Learnability	The ease of which the system functions can be learned
	Operability	The ability of the software to be easily operated
	Attractiveness	The capability of the software to be attractive to the user
Efficiency	Time behavior	Response times for a given throughput, i.e., transaction rate
	Resource behavior	Resource utilization efficiency, i.e., memory, CPU, disk and network usage
Maintainability	Analyzability	The ability to identify the root cause of a failure
	Changeability	The amount of effort to change a system
	Stability	The sensitivity to change of a given system that is the negative impact that may be caused by system changes
	Testability	The effort needed to verify (test) a system change
Portability	Adaptability	The ability of the system to change to new specifications or operating environments.
	Installability	The effort required to install the software.
	Conformance	Compliance with the comply with portability standards
	Replace-ability	The ability of the software to replace other software environment

In addition to the sub-quality factors of the "ISO 9126 Model (2001)", the following sub-quality factors are proposed as listed in Table 8.

Table 8: Definitions of the Proposed Sub-Quality Factors

Quality Factors	**Sub-quality Factors**	**Definitions of Sub-quality Factors**
Functionality	Ease of Access	The ease of access to the cloud service
Reliability	Availability	System uptime of the corresponding Cloud-EIS
Maintain-ability	Open Source Availability	Is the source code of the Cloud-EIS available to public for use and/or modification from its original design with free of charge?
Elasticity	Multi-client Access Adjustment	It is defined as the allocation of virtual resources that are shared amongst clients based on virtualization and load balancing technologies (e.g., Addition or deletion clients)
	Resource Allocation Adjustment	It is defined as the ability to upscale or downscale client IT resources when it is required. (e.g., Scaling the speed of an application, addition or removing CPU cores, CPU speed, and memory and data storage)
Security& Privacy	Authorization	It deals with integrity and confidentiality of the software. It covers *access control*, *identity management*, and *operational security* of the software. Integrity and confidentiality of the software are examined by this quality factor.
	Audit	It covers *monitoring activities* and *events*, and *logging* to prevent insecure operations in the Cloud-EIS system.
	Protection	Protection is divided into four categories which are *data protection*, *network security*, *system security* in terms of hardware, software, and *physical & environmental security of the provider's data center.*
	Multi-location Issues	Multi-location Issues are related to data center location of the Cloud-EIS provider, and covers *the location of private data*, *the location of the provider, data export across the border.*
Policy& Regulations	Compliance	It refers to the level of compliance with domain-specific standards such as HIPAA and HITECH for healthcare domain.
	Legal Requirements /Obligations	It refers to the level of compliance with legal requirements and obligations by the authorities such as government, international institutes, etc. It includes where the data is stored or how the data is exported across the country border (e.g., "Control Objectives for Information and related Technology and Safe Harbor")
Customer Service Quality	Technical Support	It is related to fixing a technical problem of the Cloud-EIS
	Customer Support	It covers the supports for installation, training, troubleshooting, maintenance, upgrading, and disposal of a product, etc.

CHAPTER 4

IDENTIFICATION and APPLICABILITY of QUALITY METRICS

In this chapter, firstly, identification and the formulation of the metrics of corresponding quality factors are presented. Accordingly, the applicability of the proposed metrics is conducted by evaluating the quality of the Cloud-EIS products. In this chapter, only the definitions of the calculated metrics are provided.

The Process of Identification of Metrics

The significant part of the metric table is that it presents the definition of the proposed KPIs of each metric, including the measurement method, interpretation of the measured value, and the aim of the metric. Thus, it provides a systematic assessment method for diagnosing the quality of Cloud-EIS products.

The metrics of each quality factor of the proposed model are developed as consistent with the metric table structure of the "ISO/IEC TR 9126-2 Software engineering – Product quality – Part 2: External metrics (2002)". According to this document, metric tables consist of following items:

- "Metric name"
- "Purpose of the metric"
- "Measurement, formula and data element computations"
- "Interpretation of measured value"
- "Metric scale type"
    - "Nominal scale, Ordinal scale, Interval scale, Ratio scale and Absolute scale"
- Measure type
    - "Size type (e.g. Function size), Time type (e.g. Processing time), Count type (e.g. Number of supported platforms of the software)"

Furthermore, the columns of the "*Method of Application", "Input to measurement", "ISO/IEC 12207 SLCP Reference", "Target Audience"* are excluded from the metrics tables, since they are out of the scope of this study.

The detailed explanations about Metric Scale Types and Measure Types are given in Appendix A.

Evaluations of Cloud-EIS Products

In order to show the applicability of the proposed metrics, three products are selected. In future work, it is planned to conduct a survey among the enterprises that implement a cloud-based logistics solution from the following three products: Gigaspaces, SAP, and OwnCloud. Therefore, these products are selected. The information related to the products is given below.

Product 1: Gigaspaces XAP Logistics and Shipping Management (2016)

Gigaspaces offers open source cloud-based industry solutions in many domains such as "Transportation & Logistics", "e-Commerce", "e-Gaming", "Healthcare", "Financial Services".

Product 2: SAP Business ByDesign Cloud ERP (2016)

SAP Business ByDesign is a SaaS application suite that offers complete and integrated enterprise information systems. "Customer Relation Management (CRM)", "Supply Chain Management (SCM)", "Finance Management (FM)", "Human Resources (HR)", and "Sales" applications are provided in the software package as well.

Product 3: OwnCloud is open source Cloud-based EIS application which offers cloud-based industry solutions in following domains: "Financial Services and Banking, Healthcare and Life Sciences, Government and Public Sector and Education".

The data for the calculation of the metric values are collected from the following documentations provided by the corresponding products' company:

- GigaSpaces XAP Documentation and Service Level Agreement (2016)
- GigaSpaces Customer Support Overview (2014)
- SAP Service Level Agreement for SAP Cloud Services (2016)
- SAP Cloud Handbook Document: "SAP Business ByDesign, SAP Cloud for Customer, and SAP Cloud for Travel and Expense"- Security Guide (2014)
- SAP "Support Essentials: What a Customer Should Know About SAP Incident Processing (2015)"
- SAP Business ByDesign Whitepapers (2016)
- OwnCloud Hardware Sizing (2013)
- OwnCloud Whitepapers & Analyst Reports (2016)

Some of the data are not found; therefore the corresponding metric value is stated as "NA", which refers to "Not Applicable".

Each metric value is calculated for at least two products from XAP, SAP, and OwnCloud, except Resource Allocation Adjustment Metric, Multi-client Adjustment. They are calculated only for one of these two products.

4.1 Functionality Metrics

Functionality factors are composed of four sub-factors which are “suitability”, “interoperability”, “accuracy”, and “ease of access”. In addition to the sub-factors of the “ISO 9126 model (2001)”, “ease of access” is proposed.

4.1.1 *Suitability Metrics*

Suitability defined as how well cloud-based enterprise application performs operational tasks required by organizations. The metric is given in Table 9.

Table 9: Suitability Metric

Metric name	Purpose of the metric	Measurement, formula and data element computations	Interpretation of measured value	Metric scale type	Measure type
Functional Suitability	Do functionalities of the Cloud-EIS meet customer needs?	X € {0, 1} 0= “not suitable” 1= “suitable”	The value of 1, is preferable.	Ordinal Scale	X= Binary

Applicability of Suitability Metric

Assume that a company looks for a suitable cloud-based logistics management, which also enable the company to record and manage customer details. The company considers selecting one of the applications from XAP and SAP Business ByDesign.

Although XAP offers transportation and logistics management, it does not manage customer profile information in detail. SAP Business ByDesign offers cloud-based logistics management, together with the Customer Relation Management (CRM) module as a business suite application. Accordingly, the metric value is given as follows:

$$X_{XAP} = 0; X_{SAP}=1; X_{OwnCloud}= 0$$

4.1.1.1 Customization Metrics

Customization is defined as the degree of modification to increase user convenience. The research question for this metric is that “How much a Cloud-EIS can be modified or built according to individual or organization specifications or preference?” Adding another language, modifying the user interface, adding the new routine business operation are common application examples of customization operations. In addition to the metrics of “customizability” in ISO 9126, the following metric is proposed as stated in Table 10.

Table 10: Customization Metric

Metric name	**Purpose of the metric**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Application Programming Interface (API) Availability	Is there any API provided in order to customize Cloud-EIS application? What is the number of APIs available in the software package for customization purposes?	X= A A= Number of available API for customization of Cloud-EIS application	0 <= X The bigger value, is the better.	Ratio	A= Count

Applicability of Customization Metric

Since GigaSpaces XAP Logistics and Shipping Management is an open source cloud-based application, it is expected to have a significant number of APIs. It offers 35 APIs and 103 packages in total for many customization operations such as managing security related alerts, adding or removing event notifications when transportation level statistics have changed, etc.

SAP Business ByDesign has an API management tool that offers 34 APIs. Users can customize their application interfaces, and provides a simplified access for their trading partner. Furthermore, they can restrict and control user entries based on security and privacy policy of the company with the utilizing corresponding API. Accordingly, the metric values are as follows:

$$X_{XAP}= 35;\ X_{SAP}=34;\ X_{OwnCloud}= NA$$

4.1.2 *Ease of Access Metrics*

Cloud-EIS offers many services that are accessible over the Internet through a Web browser. From the enterprises' point of view, ease of access to cloud services is a significant quality dimension of Cloud-EIS. Therefore, corresponding metrics are proposed as given in Table 11.

Table 11: Ease of Access Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
1. Access requirement	What is the minimum network requirement in order to access	X1= Minimum bandwidth requirements of the product (e.g., min connection speed required)	0<=X1 The smallest value of X, is	Ratio	X1=Count/Time

	in the SLA?		preferable.		
		Z= {A3, A4} Z=Minimum hardware requirement (e.g., {1GB Ram, Pentium 4, 2.4GHz } A3: Min required Ram capacity A4: Min required CPU Speed	0<=Z The smallest value of Z, is the better.	Ratio Ratio	A3=Count A4=Count/Time
2. Operating System Supportability	What is the proportion of the available supported operating system?	X1=A/B A=Number of the supported platforms B= Total number of available operating systems (e.g., Windows, Mac, Linux, mobile operating systems, etc.)	0<=X1<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count X1= Count/ Count
3. Supported Platforms	What is the proportion of the available supported platforms?	X2=A/B A=Number of the supported platforms B= Total number of available platforms (e.g., Java, .NET, C++, etc.)	0<=X2<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count X2= Count/ Count
4. Offline Access Availability	Is there any limitation of offline mode functionalities of the cloud service?	X=A/B A= Number of functionality supported in only offline mode B= Total number of functionality provided in online mode	0<=X<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count X= Count/ Count
	If an offline user made changes, What is the speed of updating and synchronization	Y=T T=Time devoted to updating and syncing to the cloud once the internet connection is established again.	0<=Y The closer to 0, is the better.	Ratio	Time

	operations?				

Applicability of Ease of Access Metrics:

Product 1: SAP Business ByDesign: Cloud-based ERP

Product 2: Gigaspaces XAP: Cloud-based Logistics and Shipping Management

1. **Access Requirement Metrics**

Minimum network requirements of SAP Business ByDesign are defined for as follows:

- Upstream: 1 Mbps
- Downstream: 1 Mbps

The following minimum port speed is required for Gigaspaces XAP:

- Upstream: 1 Mbps
- Downstream: 1 Mbps

Minimum hardware requirement of SAP Business ByDesign:

- At least 1 GB of RAM
- Pentium 4, 2.4 GHz (recommended: Intel Core 2 Duo, 2.4 GHz)

Minimum hardware requirements Gigaspaces XAP:

- At least 2GB of free RAM
- 4 X 2.0 GHz

OwnCloud requires a minimum of 128MB RAM. Therefore, the metric values are as follows:

$X1_{SAP}$= 1Mb (2Mb recommended); $X1_{XAP}$=1Mb; $X1_{OwnCloud}$= NA

Z_{SAP}= {1 GB Ram, Pentium 4, 2.4 GHz}; Z_{XAP}= {2 GB Ram, NA, 2.0 GHz}; $Z_{OwnCloud}$= {128 MB Ram, NA, NA}

2. **Operating System Supportability**

Available operating systems can be defined as a set of operating systems that are available in the market. In this study the set of operating systems is defined as follows:

$$Z_{os}= \{\text{Microsoft Windows OS, Mac OS, Linux, UNIX, Solaris, Mobile Operating Systems}\}$$

SAP Business ByDesign supports only Microsoft Windows 7 or 8.1, Mac OS with Apple Safari 8 or supported Firefox 40, and mobile operating systems (e.g., Android, IOS), whereas Gigaspaces's XAP supports only "Windows 2008 Server SP2", "Linux RHEL 5. X" and "Solaris 10" and "UNIX "from the members of the set of B. OwnCloud supports Windows, Linux, and mobile operating systems such as iOS 7+, and Android 4+. Therefore, the values of the metrics are calculated as follows:

$$X1_{SAP} =3/6;\ X1_{XAP} =5/6;\ X1_{QwnCloud}=3/6$$

As a conclusion, XAP supports more platforms than SAP and OwnCloud.

3. Supported Platforms Metric

GigaSpaces' XAP has platform interoperability with Java, .NET and C++ platforms. They can work together and communicate with each other easily and efficiently.

SAP Business ByDesign has many community networks for Java, .NET and others. ABAP Development, Java Development, SAP Net Weaver Business Warehouse are some examples of them. Therefore, the values of the metrics are calculated as follows:

$$X2_{XAP} =3/3;\ X2_{SAP} =3/3;\ X_{QwnCloud}=NA$$

4. Offline Access Availability

Three products have offline access to operate the system. And, there is no limitation of the functionalities while the offline mode is active. In that case, updating and synchronizing changes made once a network connection is again established are significant for obtaining real time information of business flow. Therefore, the syncing performance of each product is examined.

In the documentation of the XAP (2016), the syncing process of the XAP is described as follows "Changes in the server are grouped and sent to the client in batches. The default is 1000 objects in a batch. The default Synchronization is 100 milliseconds."

OwnCloud keeps one version every 200 milliseconds. As for SAP Business ByDesign, the metric value is not found. Therefore;

$$Y_{XAP} = 100 \text{ milliseconds};\ Y_{SAP} = NA;\ Y_{OwnCloud} = 200 \text{ milliseconds}$$

4.2 Reliability Metrics

Reliability factors are composed of four sub-factors which are maturity, fault tolerance, recoverability, and availability. Since the availability (uptime) of cloud-based application is important for the sustainability of the service provided, in addition to reliability metrics of ISO 9126, the following metric is proposed as stated in Table 12.

Applicability of Reliability Metric

Availability of the three products is provisioned as application availability, and it is stated as 99.9%. Therefore, the values of the metric are stated as follows:

$$X_{SAP} = 0.999;\ X_{XAP} = 0.999;\ X_{OwnCloud} = 0.999$$

Table 12: Availability Metric

Metric name	Purpose of the metrics	Measurement, formula and data element computations	Interpretation of measured value	Metric scale type	Measure type
System Uptime	What is the percentage of the system uptime within the specified operation period?	X= {To / (To + Tm)} X=system uptime To = Operation time Tm = Time dedicated to maintenance (downtime)	0<=X<=1 The closer to 1, is better	Ratio	X=Time/Time To=Time Tm=Time

4.3 Usability Metrics

Usability metrics are derived from the quality model of ISO 9126. It covers metrics of understandability, learnability, operability and attractiveness.

Since all attributes of usability dimension are subjective, the usability of Cloud-EIS can be evaluated by employing survey amongst actual users of Cloud-EIS. The usability of the corresponding products should be studied more systematically. For this purpose, “System Usability Scale (SUS) instrument”, which consists of 25 questions related to usability, can be employed. As stated in EIC ISO 9126 External metrics (2002), usability test should be conducted at least 8 people who directly interact with the software. Since SUS-based test is out of scope of this study, it is planned to conduct a usability test for each Cloud-EIS product in future work.

4.4 Efficiency Metrics

Efficiency factors are composed of two sub-factors which are time behavior or resource behavior of the software. The metrics related to “efficiency” are defined as stated in Table 13 and Table 14.

4.4.1 *Time Behavior Metric*

The metric of response time developed based on the “ISO 9126 Software Quality Model”. This metric evaluate the software performance with respect to the response time of a service request. How timely the software responds to a service request is evaluated by these metrics as stated in Table 13.

Table 13: Time Behavior Metric

Metric name	Purpose of the metrics	Measurement, formula and data element computations	Interpretation of measured value	Metric scale type	Measure type
Response Time	What is the upper limit to complete a specified operation?	T = T(available) –T(request) T(available)= Time of when the request is available T(request)= Time of when a user requests a service	0<=T<= T(max) The smaller value of T(max), the better.	Ratio	T= Time

Applicability of Time Behavior Metric

Gigaspace XAP provisions in SLA that the maximum response time is 1000 milliseconds. To examine the response time of the product, the query as seen from Figure 5 is conducted and it is noted that the query response time is 23 milliseconds which is under 1000 milliseconds as stated in the SLA.

Figure 5: The Query Example

```
Select region, <waitingForPickupCount>, sum<inTransitCount>,
sum<arrivalScanCount>, sum<outForDeliveryCount>. sum<deliveredCount>
from. gigaspaces. logistics. model. Package Statistics WHERE StatType='Region'
grouped by region
```

This query is repeated ten times sequentially and every time it returns the result under 1000 milliseconds. The response times of subsequent query are 13, 16, 13, 15, 16, 10, 23, 75, 10, and 15 respectively.

As for SAP Business ByDesign, it is stated that the response time of the application is provisioned between 300 - 500 milliseconds. To learn whether there is a track request from the wholesaler, a query is conducted from the Self-Service Overview Menu of SAP Business ByDesign (2016); it returns the result in less than 500 milliseconds as stated in the SLA.

$$X_{XAP} = 1000ms;\ X_{SAP} = 500ms;\ X_{OwnCloud} = NA$$

4.4.2 *Resource Behavior*

This metric is developed based on the "ISO 9126 Software Quality Model". How efficiently the software utilizes resources are assessed by following metric as stated in Table 14.

Table 14: Resource Behavior Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Resource requirements	What are the lower limits of hardware requirements in order to operate Cloud-EIS?	Z= {X, Y, Z} X= min required Ram Y= min required CPU Z= min required Disk memory	0<= X, Y, Z The smaller values, the better efficiency.	Ratio	X, Z= Absolute Y=Count /Time

Applicability of Resource Behavior Metrics

The sets of the resource behavior metric of two products are stated follows:

Z_{XAP}= {8GB, 4 X 2.0 GHz Cores, 25 GB (SAN)}; Z_{SAP} = {2GB, 2 X 2.4 GHz Cores, 30GB (Database)}; $Z_{OwnCloud}$ = NA

Note that the value of this metric can be changed according to the total number of system users. In this example, the metric value calculated for 20-30 users.

4.5 Maintainability

Maintainability consists of five sub-factors which are analyzability, changeability, stability, testability, and open source availability. In addition to ISO 9126 maintainability metrics, following metric is proposed as stated in Table 15.

Table 15: Maintainability Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Open Source Availability	Is the source code of the Cloud-EIS available public use and/or modification from its original design with free of charge?	X € {0, 1} 0= " not open source" 1= "open source"	It depends on the corresponding company policy.	Ordinal Scale	X= Binary

Applicability of Maintainability Metric

Since OwnCloud and XAP are open source cloud-based applications, the metric value of each product is stated as follows:

$$X_{SAP} = 0;\ X_{XAP} = 1;\ X_{OwnCloud} = 1$$

4.6 Portability

Portability consists of four sub-factors which are adaptability, installability, conformance and replace-ability. In addition to replace-ability metrics of ISO 9126 External Metrics (2002), the following metrics are proposed as listed in Table 16.

Table 16: Portability Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Migration support	Is there a migration support mechanism in Cloud-EIS software?	X € {0, 1} 0= "there is no migration support tool" 1="there is a migration support tool"	Most of the company prefers the software with migration support tool.	Ordinal Scale	X= Binary
Data export Capability	Does the data export capability of Cloud-EIS meet customer needs?	X € {0, 1} 0= "no" 1="yes"	The value of "1", is the better.	Ordinal Scale	X= Binary
System Setting Configuration	How easy system setting configuration is applied to Cloud-EIS?	T= Time devoted to configuration operations in minutes	0<T<Max(T) The smaller value of Max(T), the better.	Ratio	T= Time

Applicability of Migration Support Metric:

SAP Business ByDesign has Advanced Data Migration by BackOffice Associates in order to simplify migration and prevent data loss during the migration period to the cloud. This migration support mechanism significantly reduces migration effort and deployment delays.

GigaSpaces XAP has an External Data Source API that includes 5 interfaces to data migration support which are as follows:

- “ManagedDataSource” is available for loading initial data.
- “DataProvider” can read data by using a template.
- “SQLDataProvider” reads data by using SQL queries.
- “DataPersister” transfers non-transactional data to the destination.
- “BulkDataPersister” transfers batched or transactional data to the destination.

$$X_{SAP} = 1; X_{XAP} = 1; X_{OwnCloud} = 1$$

Applicability of Data Export Capability Metric

Assumption: A company migrating to the Cloud-SCM has specified following data export capability for selecting adequate product from alternatives:

- Data of shipment information and trading partner’s records can be exported with encryption into XML and XSL files in order to protect private and company data.
- Software should have Data Export Compliance Certificate for global trade regulations that ensure protecting private data of the company, and reduce the possibility of fines and other punishments sourcing from non-compliance and compliance expenses sourcing from procedures of data export.
- It should automate data export from Cloud-SCM to logistics reporting systems (LOGREP), deployment and movement systems (ADAMS), and other allied systems.

GigaSpaces XAP has Task Execution API, provide data export automation with two-way encryption algorithms. With this API, data export from XAP to another system can be automated.

SAP Technical Data Export Compliance prevents unapproved exports of personally identifiable information and supports the operation of data export with encryption into a different type of the files including HTML, XML, CSV and XSL and consistent with international standards and legislation related to data export. It also automates data export from SAP to NATO systems which are Allied Deployment and Movement Systems (ADAMS), Logistics Reporting Systems (LOGREP). It also offers automation for data export for other allied systems.

Since OwnCloud does not provide any logistics management application on the cloud, it is out of scope.

The metrics values as follows:

$$X_{SAP} = 1; X_{XAP} = 1; X_{OwnCloud} = 0;$$

As seen from metric values, this company can prefer implementing SAP Business ByDesign or XAP.

Applicability of System Setting Configuration Metric

It is stated in the document of OwnCloud (2016), the system configuration for a event creation can take less than 5 minutes.

SAP configuration time limit (i.e., Event creation configuration) can take from 1 to 15 minutes.

XAP configuration time limit for an event configuration is specified as 15 minutes.

$$X_{SAP} = 15 \text{ minutes}; X_{XAP} = 15 \text{ minutes}; X_{OwnCloud} = 5 \text{ minutes}$$

4.7 Elasticity

Since elasticity is one of the major characteristics of the cloud computing, the following metrics proposed as listed Table 17.

Table 17: Elasticity Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Multi-client Access Adjustment	How IT resources are shared among the users based on virtualization and load balancing technologies?	X= Max (X) X=Maximum instances per Virtual Machine	0<=X The bigger number of X, the better.	Ratio	X=Count
		N= Max number of users that can access the Cloud-EIS concurrently	N< Max(N)	Absolute	N=Count
Resource Allocation Adjustment	What is the capacity of up-scaling or down-scaling user IT resources when required?	T= Time devoted to scaling operation	0<T The smaller value of T, is better.	Ratio	T= Time

	What is the interval of memory sizing of resource allocation operation?	Z =[Min(Z);Max(Z)] Z=Allocated Memory per client	Min(Z)<Z< Max(Z) The closer to Max (Z) is, the better.	Interval Scale	Z=Interval

Applicability of Elasticity Metrics

XAP provides services concurrently from 1000 up to 4000 users. Initial deployment memory capacity is 32 GB. Max capacity memory capacity can be allocated to a user as 64GB with 4GB JVM heap size.

In the software, with *max-instances* parameter sets the maximum number of instances that can be allocated on a single JVM or on a single machine. A machine running 4 quad-core cores with 3 GHz-CPUs can process 20-30 concurrent adjoined clients without any delay when business logic is not complicated.

In the software, *instances-per-vm* parameter defines the total number of instances a partition can have within a Grid Service Container (GSC). In order to control maximum number of instances per Virtual Machine (VM), the following arrangement can be set before running:

Figure 6: Arrangement of the number of Instances per VM in Gigaspaces XAP

```
GSC: set GSC_JAVA_OPTIONS=-Dcom.gigaspaces.grid.gsc.serviceLimit=2

com.gigaspaces.grid.gsc.serviceLimit = 500
```

OwnCloud users are limited to 10 GB, and the number of max users is initially defined as 400. Depending intensity and pattern of use, appliance scales to 250 users as “normal user”. For memory sizing, if there is a need the capacity can be scaled up to 32 GB. However, storage, memory, CPU of client affects to the number of users, and the number of maximum users is defined as 100000 in OwnCloud products.

SAP Business By Design can handle 28000 threads per second. The limit number of the user for a session can be arranged according to organizations’ size. The default value is equal to 200. However, an enterprise can restrict or enlarge the session size from the menu of Properties from the dashboard.

Note that the following metrics except Max number of users is calculated according to the number of “normal user” of each product. Therefore, the metric values are stated as follows:

$$X_{SAP} = 28000;\ X_{XAP}=500;\ X_{OwnCloud} = NA$$

$$N_{SAP} = 200+;\ N_{XAP} = 4000;\ N_{OwnCloud} = 100000$$

$$T_{SAP} = 60 \text{ seconds};\ T_{XAP} = NA;\ T_{OwnCloud} = NA$$

Z_{SAP}=NA; Z_{XAP}=[32GB; 64GB] ; $Z_{OwnCloud}$=[10GB; 32GB]

Although there are Not Applicable (NA) metric values, it can be concluded that XAP and SAP are more powerful than OwnCloud product with respect to the elasticity of the services they provide.

4.8 Security & Privacy

After a literature review, it is concluded that there are a few studies that propose quality metrics for qualifying security and privacy level of Cloud-EIS.

For this aim, the ISO 270017 Security Issues for Cloud Services and the ISO 270018 Privacy Issues for Cloud Services, providing security and privacy techniques for cloud services, are considered as a baseline in order to develop security and privacy metrics for Cloud-EISs.

In the proposed quality framework, security and privacy issues are mainly grouped as authorization, audit, protection, and multi-location issues.

Metrics of Authorization and Audit are derived from the "ISO 9126-2 Software Engineering- Product Quality-Part 2: External Metrics (2002)".

In addition to the security dimension of the ISO 9126 Model, Protection and Multi-location Issues are proposed as a sub-dimension of Security. Protection metrics are divided into four categories below:

- Data protection
- Network security
- System security in terms of hardware and software
- Physical & environmental security of provider's data center

Multi-location Issues are defined as four items as stated below:

- Location of private data
- Location of Cloud-EIS provider
- Data transfer across the border

In addition to metrics of *Access auditability*, *Access controllability*, *Data corruption prevention* in the ISO 9216 Model, following metrics with respect to Protection and Multi-location Issues are proposed as listed in Table 18.

Table 18: Security and Privacy Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**

Fatal Data Corruption	What is the proportion of fatal data corruption incidents sourcing from memory and hard-drive corruption?	X= 1 – A / B A= Number of fatal data corruption incidents during specified period of time B= Total number of test cases tried to cause fatal data corruption incidents	0<=X<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count F= Count/ Count
Network Security	What is the frequency of the event of network failure?	N= 1 – A / B A= Number of network failure incidents during specified period of time B= Total number of test cases tried to cause network failure incidents	0<=N<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count N= Count/ Count
System Security	What is the frequency of the software/ hardware failure?	S= 1 – A / B A= Number of the system failure incidents during specified period of time B= Total number of test cases tried to cause system failure in terms of hardware and software	0<=S<= 1 The closer to 1, is the better.	Absolute	A= Count B= Count S= Count/ Count
Physical and Environmental Security	Does physical and environmental security level of the provider's data center meet user expectation?	P € {0, 1} 0= "provider does not meet user expectation" 1= "provider meets user expectation"	The metric value of 1 is preferable.	Ordinal Scale	P= Binary
Multi-location Issues	Do multi-location issues of the cloud service threaten private data on the cloud? Does multi-location policy meet client requirements?	M € {0, 1} 0= "the policy of multi-location issues does not meet enterprise requirements" 1= "the policy of multi-location issues meets enterprise requirements"	The metric value of 1 is preferable.	Ordinal Scale	M= Binary

Applicability of Security & Privacy Metrics

Since first three metrics need a test case in order to identify the frequency of related failure, they can only be calculated after testing of software. Because of this reason, data for calculating the values of these metrics cannot be obtained without testing the corresponding Cloud-EIS software. Therefore, data for them cannot be collected. It is planned to be assessed in future work.

Assume that a company looks for suitable Cloud-SCM to implement. Suppose that it has following specifications related to company security and privacy policy:

- Data should be stored with two-way function encryption algorithms such as AES 128-bit.
- Middle-box such as firewall, packet filters should be utilized for protection against to malware.
- Communication security should be enhanced with VLAN, SSL, Hypervisor based Filter (a sort of on-demand security filter for networks) in order to prevent network failure and to obtain the secure network system.
- Authentication should be secured by client certification.
- The product should have a certificate of compliance for standard ISO 27001 Information Security Management for Cloud Services.
- A provider's data center should be located in the United States of America and data center operations meets security and privacy requirements stated in the ISO 27001 standard. Furthermore, physical and environmental security of data center location, such as security of the equipments, and access management in the buildings of data center should meet the requirements stated in the ISO 270017 and the ISO 270018 standards.
- Data transfer across the border should be in a secure way that unapproved exports of personally identifiable information or private data revelation should be prevented. As stated in Section 13.2 of the ISO 27001 and the ISO 27001 standards, Information Transfer across the border should be secured. An additional encryption method is required to ensure that the data can only be accessed at the point of the target, and to protect PII from potential any harmful attack.

Data centers of the SAP are located in the USA and Germany, and secured by staff 365 days a year. Only authorized personnel access the data center buildings. Furthermore, data center security is certificated by the ISO 27001 (SAP Data Center Operations) and the ISO 27001 (SAP Cloud Operations). Encrypted storage is used to protect private data and other company data. While offline working mode is active, data is encrypted and then stored on the device until the network connection established again and syncing operation is completed. SAP has also trust certification, which is called Trust Center Universal CA I from Entrust.net Secure Server Certification Authority. For authentication, SAP supports the following mechanism:

- Logon using SAML 2.0 assertion for front-end Single Sign-On (SSO)
- Logon using client certificate (X.509) as logon certificate
- Logon using user ID and password

Data centers of Gigaspaces' products are located in the USA. The security requirements of the data center buildings are satisfied. Data stored with a two-way function encoding algorithm which is AES 128-bit. It needs a private key to encode and decode. XAP employs TLS protocol for encryption. For password encoding, MD5 which is a one-way hash function is used as default algorithm for authentication validation. The UI, CLI and Admin API offer wide-ranging support to secure processes of authentication.

The metric values of Fatal Data Corruption, Network Security, System Security and Physical and Environmental Security are not calculated. Because the calculation needs observation of the frequency of a security related events over a long period of time, and direct interaction with the corresponding software. Therefore, it is planned to be conducted in future work. Therefore, the corresponding metric values are stated as follows:

$$X_{SAP}= 1; X_{XAP}= 1; X_{OwnCloud}=NA$$

4.9 Policy & Regulations

Policy and Regulations is divided into two sub-quality factors which are Compliance and Legal Requirements / Obligations. The metrics are listed in Table 19.

Table 19: Policy and Regulations Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Compliance	How compliant is the software with related domain specific standards or regulations? (e.g., Compliance with regulations such as HIPAA and HITECH should be examined, if application domain is related to healthcare and life sciences)	X € {0, 1} 0: "Cloud-EIS is not compliant with related domain specific standards" 1: "Cloud-EIS is compliant with related domain specific standards"	The value of metric "1" is more preferable.	Ordinal Scale	X=Binary
Legal requirements/Obligations	How compliant is the software with related legal requirements or obligations, conventions, and other standards? *Note that:* This metric closely related to government policy and its strategies towards to cloud technologies as well.	X € {0, 1} 0: "Cloud-EIS is not compliant with related domain specific standards" 1: "Cloud-EIS is compliant with related domain specific standards"	The value of metric "1" is more preferable.	Ordinal Scale	X=Binary

Applicability of Policy & Regulations Metrics

These metrics evaluate whether the product meet the legal requirements and obligations and other domain specific standards, or not.

Assume that there is a Canadian company looks for suitable Cloud-based Healthcare application from two alternatives which are XAP for Healthcare IT and OwnCloud Healthcare and Life Science. The suitable software should comply with domain specific standards or regulations and legal requirements/ obligations.

OwnCloud has complied with legislation that Canadian Government push companies to obey "Digital Privacy Act upon the Personal Information Protection and Electronic Documents Act (PIPEDA)". OwnCloud and XAP Healthcare applications are also consistent with "HIPAA" and "Health Information Technology for Economic and Clinical Health (HITECH) Act", which ensure the content security of the software application. Since SAP is out of the scope of the assumption, the metric values are as follows:

$$X_{XAP}= 1; X_{OwnCloud}=1$$

4.10 Customer Service Quality

The metrics of Customer Service Quality are developed to qualify the level of quality of providers' customer service. 24x7 technical/customer support availability, the time consumed for fixing a problem, and availability of a dedicated support team are identified as attributes of customer service quality. Related metrics are categorized into two groups which are Technical Support and Customer Support. The technical support team attempts to help the user to solve technical problems with the product of Cloud-EIS rather than providing training or other support services. Whereas, customer support team helps clients for efficient use of Cloud-EIS product. The assistance of the customer support team covers helps for many issues such as installation, training, troubleshooting, maintenance, upgrading, and disposal of a product, etc. The metrics are listed in Table 20.

Table 20: Customer Service Quality Metrics

Metric name	**Purpose of the metrics**	**Measurement, formula and data element computations**	**Interpretation of measured value**	**Metric scale type**	**Measure type**
Customer Service Availability	What are the customer service hours of operation?	T1 T1= Working hours of customer service department of the cloud provider	0<=T1 The closer to 24 hours, is the better.	Ratio	T1= Time

Customer Service Availability	What is the number of available communication channels in the department of provider's customer service?	Y=C/D C= Number of the customer support channel for a client D=Total number of customer support channel	0<=Y <=1 The closer to 1, is the better.	Absolute	Y= Count / Count
Technical Support	What is the time interval for fixing a technical problem of the Cloud-EIS?	T2= [a, b] T2= Time interval dedicated to fixing a problem sourcing technical aspect of the software	0<=T2 The closer value of (a-b) to 0, the better.	Interval Scale	T2,a, b= Time
Customer Support	What is the time interval for responding a help request from a customer?	T3= [a, b] T3= time interval for responding a help request	0<=T3 The closer value of (a-b) to 0, the better.	Interval Scale	T3,a, b = Time
Priority of Incidents	Is there a priority classification of incidents that are reported to customer service?	Xpriority € {0, 1} 0: There is no priority classification of incidents reported 1: There is a priority classification of incidents reported	The priority classification is preferable.	Ordinal Scale	X=Binary

Applicability of Customer Service Quality Metrics

SAP Business ByDesign, XAP and OwnCloud have a customer service that is available 24 hours a day, 7 days a week. Therefore the corresponding metric value is stated as below:

$$T1_{SAP\ =}\ 24x7;\ T1_{XAP}=24x7;\ T1_{OwnCloud}=24x7$$

SAP Business ByDesign has provisioned customer to fix the following problems through customer support team:

- An error/defect in the software
- Unexpected results
- Questions on configuration and customization
- Help for installation or upgrade

SAP Business ByDesign has categorized problems according to their priority. If an incident with very high priority occurs, the problem will be confirmed within 14 days. For incident for very low priority, this period can be extended up to 45 days.

Gigaspaces products have also priority management on solving problem incidents reported by clients, and response time limit is stated in products' SLA.

$T2_{SAP =}$ [14 days, 45days]; $T2_{XAP}$ = [2 days, 30 days]; $T2_{OwnCloud}$ =[1 days, 30 days];

$T3_{SAP =}$ [1 hours, 3 business days]; $T3_{XAP}$ = [2 hours, 4 business days]; $T3_{OwnCloud}$ = [2 hours, 4 business days]

Accordingly, the metric value of Priority of Incidents is given below:

$Xpriority_{SAP =}$ 1; $Xpriority_{XAP}$ = 1; $Xpriority_{OwnCloud}$ =1

Channels of communication for customer service can be "phone support", "live chat support", "e-mail support", and "social media platforms (e.g., Facebook, Twitter, YouTube, LinkedIn) support". It can be defined as a set of platforms as follows:

Z= {Phone Support, E-mail Support, Live Chat Support, Support from Social Media}

SAP Business ByDesign, XAP, and OwnCloud have all channels of communication for service support of their products. OwnCloud has 8hours in 5week days email support and 24 hours in 7 days phone call supports for their clients. Therefore, corresponding metric values are calculated for each provider as follows:

$Y_{SAP =}$ 4/4; Y_{XAP} =4/4; $Y_{OwnCloud}$ =4/4

As seen from the values of metrics, it can be concluded that OwnCloud has relatively more efficient customer support because of having minimum response time to a problem reported by customers.

4.11 Applicability of Other Sub-factors

Some metric values of the sub-quality factors of Cloud-EIS are not calculated. Because the calculation needs long-term observations on the corresponding event occurrence in a specified period of time (e.g., Frequency of network failure, the number of faults eliminated over time, etc.). Therefore, it is planned to be studied in future work. The status of the metrics are listed in Table 21.

Table 21: Summary of the Calculation of the Metric Value

Quality Factors	**Sub-quality Factors**	**Status**
Functionality	Suitability	Calculated
	Interoperability	To be calculated
	Accuracy	To be calculated
	Ease of Access	Calculated
Reliability	Maturity	To be calculated
	Fault Tolerance	To be calculated
	Recoverability	To be calculated
	Availability	Calculated
Usability	Understandability	To be calculated
	Learnability	To be calculated
	Operability	To be calculated

	Attractiveness	To be calculated
Efficiency	Time behavior	Calculated
	Resource behavior	Calculated
Maintainability	Analyzability	To be calculated
	Changeability	To be calculated
	Stability	To be calculated
	Testability	To be calculated
	Open Source Availability	Calculated
Portability	Adaptability	To be calculated
	Install ability	To be calculated
	Co-existence	To be calculated
	Replace-ability	Calculated
Elasticity	Multi-client access adjustment	Calculated
	Resource allocation adjustment	Calculated
Security & Privacy	Authorization	Calculated
	Audit	Calculated
	Protection	Calculated
	Multi-location Issues	Calculated
Policy & Regulations	Compliance	Calculated
	Legal Requirements/ Obligations	Calculated
Customer Service Quality	Technical support	Calculated
	Customer support	Calculated

CHAPTER 5

RANKING of the QUALITY FACTORS

In this chapter, the ranking of the quality factors of Cloud-EIS and interpretations of the quality model are provided. First, the ranking of the quality factors is performed with a survey designed with the Analytic Hierarchy Process (AHP) method. Then, the survey is distributed among 35 experts that are knowledgeable about cloud computing and enterprise information systems. Consequently, the weight of each quality factor has been obtained. Finally, the quality model of Cloud-EIS has been interpreted based on the weights of the quality factors, and the findings of the AHP survey are presented.

5.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) method which is one of the most popular approaches in Multi-Criteria Decision Making (MCDM) problems is proposed by Saaty (1980). The AHP is a theory of measurement that provides structured method for managing and examining complicated decisions. It relies on individuals' judgments based on pairwise comparison of the corresponding items.

The AHP method has a hierarchical structure. First, the method decomposes complicated and multi-criteria problems into a comprehended sub-problems that can be studied independently. Then the pairwise comparisons are conducted by individual decision makers. The AHP method can be applied in various domains such as government, business, industry, healthcare, etc.

The AHP method is commonly applied to study hierarchically-structured multi-criteria problems such as prioritizing, the selection of the best alternatives, investment problems, etc. (Saaty, 1990), and many researchers have applied the AHP method to study the quality of Cloud Computing based services (Garg et al., 2013). Since the quality model of Cloud-EIS consists of 10 main quality factors and 33 sub-quality factors in total, and it is hierarchically-structured, the AHP method is found as an efficient and suitable method to investigate the quality model of Cloud-EIS.

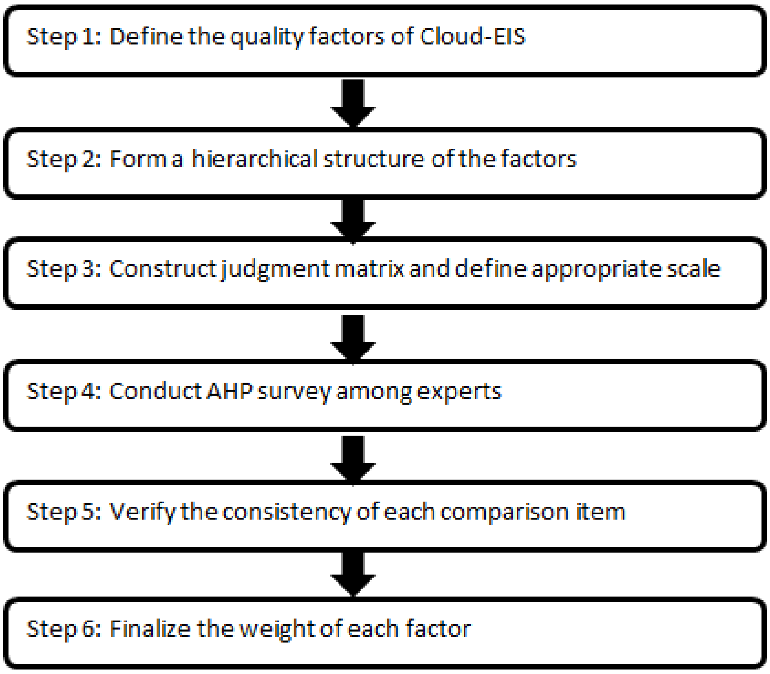

Figure 7: The Stages of the Ranking of the Quality Factors of Cloud-EIS

In order to employ the AHP method, the steps stated in Figure 7 are followed. First of all, the experts have defined the quality factors of Cloud-EIS from the literature, and formed the hierarchical structure of these factors as explained in Chapter 3. Consequently, the judgment matrix is constructed based on the AHP method, and the Saaty's Scale is selected to express individual preferences for the comparison of the items as explained in Section 5.2 and Section 5.3. Then, the surveys are distributed among the experts. After receiving survey responses, the consistency of each survey response is checked as explained in Section 5.6. Finally, the consistent survey responses are collected, and the weight of the each factor is calculated as stated in Section 5.7. The analysis of the survey responses from two samplings groups, which are PhD students and Experts, is presented in Section 5.8.

5.2 Hierarchical Form of Quality Model

Since the quality model of Cloud-EIS is hierarchically structured, the survey incorporates pairwise comparisons of the quality factors within the two-level hierarchy. First level hierarchy consists of main quality factors of Cloud-EIS, while second level hierarchy is composed of sub-quality factors of Cloud-EIS. The hierarchies of the quality factors can be seen from Figure 8.

First of all, the responders are requested to rank main quality factors within the first level of the hierarchy. Then, sub-factors of each quality factor are ranked within the second level of the hierarchy. For example, at the first stage of the survey, "functionality" and other 9 main quality factors are ranked based on pairwise comparison method, and the weight of each main factor is obtained. Then, sub-factors of each main factor are ranked, and the weight of each sub-factor is calculated. For instance, suitability, interoperability, accuracy, and ease of access are ranked within the sub-factors of "functionality".

Main Quality Factors (Level 1)	**Sub-quality Factors (Level 2)**
Functionality	Suitability
	Interoperability
	Accuracy
	Ease of Access
Reliability	Maturity
	Fault Tolerance
	Recoverability
	Availability
Usability	Understandability
	Learnability
	Operability
	Attractiveness
Efficiency	Time Behavior
	Resource Behavior
Maintainability	Analyzability
	Changeability
	Stability
	Testability
	Open Source Availability
Portability	Adaptability
	Installability
	Co-Existence
	Replace ability
Elasticity	Multi-client Access Adjustment
	Resource Allocation Adjustment
Security & Privacy	Authorization
	Audit
	Protection
	Multi-Location Issues
Policy & Regulations	Compliance
	Legal requirements/ Obligations
Customer Service Quality	Technical Support
	Customer Support

Figure 8: Hierarchical Form of the Quality Model of Cloud-EIS

5.3 Survey Design

AHP necessitates a scale for the expression of the degree of individual judgment in pairwise comparison. Although any scale can be developed for the exclusive condition of prioritizing, the Saaty's Scale is found as consistent with the main purpose of ranking the quality factors. Therefore, the scale of Saaty is employed to express individual preferences for the comparison.

Fundamental Scale Row (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderatly less important	1/3
	1/2
Equal Importance	**1**
	2
Moderatly more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Figure 9: Survey Scale (Saaty, 1990)

The scale used for the ranking of the pairs is from 1 to 9 numerical values, where a linguistic judgment of “equally important” is equal to 1, to a linguistic judgment of “extremely important” which is equal to 9 (Saaty, 2000). As seen from Figure 9, This scale converts a linguistic judgment into the numerical measure that represents the relative importance of the corresponding comparison items.

In this study, the AHP template of SCB Associates (2016), which is available on the website of the organization, is customized and employed to rank the quality factors of Cloud-EIS. Detailed information is given in Appendix B.

Analytic Hierarchy Template: n=	4	Criteria

Fundamental Scale (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal Importance	1
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Priorities for Sub-characteristics of "Functionality"

Pairwise Comparison Matrix

	Suitability	Interoperability	Accuracy	Ease of Access	~~Requirement~~
Suitability	1	4	3	2	~~1~~
Interoperability	1/4	1	1/2	1/3	~~1~~
Accuracy	1/3	2	1	1/2	~~1~~
Ease of Access	1/2	3	2	1	~~1~~
~~Requirement 5~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 6~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 7~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 8~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 9~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 10~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 11~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 12~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 13~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 14~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 15~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~

Figure 10: A Screenshot of the Survey Conducted (Judgment Matrix)

As seen from Figure 10, the pairwise comparison of the sub-factors of “functionality” is conducted.

	AHP		Consistency check
1	0,480	48,0%	Consistency OK
2	0,103	10,3%	2%
3	0,155	15,5%	
4	0,262	26,2%	
5	~~0,000~~	~~0,0%~~	
6	~~0,000~~	~~0,0%~~	
7	~~0,000~~	~~0,0%~~	
8	~~0,000~~	~~0,0%~~	
9	~~0,000~~	~~0,0%~~	
10	~~0,000~~	~~0,0%~~	
11	~~0,000~~	~~0,0%~~	
12	~~0,000~~	~~0,0%~~	
13	~~0,000~~	~~0,0%~~	
14	~~0,000~~	~~0,0%~~	
15	~~0,000~~	~~0,0%~~	

Figure 11: A Screenshot of Calculation of the Weights

As seen from Figure 11, the weights *of suitability, interoperability*, *accuracy* and *ease of access* are calculated as 0.480, 0.103, 0.155 and 0.262 respectively. Once the responders complete the pairwise comparison, the consistency of the survey is calculated automatically. In this example, the consistency of the comparison is calculated as 2%, which shows the responder has made consistent judgments and there is no inconsistent answer among the comparison pairs. If this value exceeds 10%, the responder is requested to revise his/her judgments.

5.4 Responder Profile

The survey has been distributed among 35 responders (experts) in Turkey that are knowledgeable about cloud computing and enterprise information systems. The responders of the survey consist of 15 PhD students and 20 Experts working with an enterprise information system in a company.

5 responders from 15 PhD students are pursuing their PhD in the Department of Electrical and Electronics Engineering, while 10 of them are PhD students in the Department of Information Systems. From 20 Experts, 8 of them are working as IT Specialist in the company, while 12 of them interact with an enterprise information system to assist his/her daily activities in the company.

5.5 Complexity of Survey

The survey designed with AHP method has a time complexity of pairwise comparisons. There is a positive relation between time consumed for a pairwise comparison and the total number of items being compared.

The number of items being compared is calculated by the following formula:

$$\text{“}n \times (n-1)/2\text{”}$$

Where n represents the total number of the quality factors being ranked. Accordingly, the complexity of each comparison item is calculated as stated below.

Since there are 10 main quality factors, the number of pairwise comparisons is calculated as follows:

$$10 \times (10-1) / 2 = 45 \text{ pairs}$$

Functionality, reliability, usability, portability, and security and privacy have 4 sub-factors, while maintainability has 5 sub-factors and the rest of main quality factors have 2 sub-factors, the complexities of the sub-factors comparisons are calculated as follows:

$$[5 \times 4 \times (4-1) / 2] + [5 \times (5-1) / 2] + [4 \times 2 \times (2-1) /2] = 44 \text{ pairs}$$

Thus, the total number of the comparison pairs is equal to 89. And, the average time spent on a survey is between 45 minutes- 60 minutes.

5.6 Consistency of the Survey

After receiving the survey responses from 35 responders, the consistency of each comparison item has been checked before calculating the weights. Inconsistent responses have been discarded or the responder is requested to revise his/her response.

According to the algorithm of the consistency ratio calculation, at least three items should be prioritized. For instance, if a responder prioritizes the factors within 3x3 comparison matrix consisting of three items which are A, B, and C;

If the judgment of the comparison pair of (A and B) is A>B

And the judgment of the comparison pair of (A and C) is C>A

The judgment of the comparison pair of (B and C) should be C>B; otherwise, the responder decision will be inconsistent with first two pair comparisons.

Calculation of Consistency Ratio

In order to check whether the judgments of responders are consistent, Consistency Index (CI) and the Consistency Ratio (CR) should be calculated respectively as follows (Saaty, 2008);

$$\text{“}CI = (\lambda_{max} - n) / (n - 1)\text{”}$$

$$\text{“}CR = CI / RI\ (n)\text{”}$$

In the equation, RI is a Random Index (the average consistency index) which is an average of a randomly produced pairwise matrix of the similar preference, and n is the total number of items being compared, and λ_{max} refers to principal eigenvalue.

Consistency Ratio (CR) of each comparison pair of the survey should not be greater than 10% if the comparison matrix incorporates with five or more than five factors (Saaty, 1990).

After CR is calculated, the responses of each survey should be checked whether there is an inconsistency in comparison item. The consistency of each comparison item within the survey is checked according to Table 22.

Table 22: Consistency Check

Matrix size	**Threshold value of CR**	**Items**
2x2 matrix	The comparison of two items has always 0% CR.	Efficiency, Elasticity, Policy& Legal Requirements/Obligations, Customer Service
3x3 matrix	It should be less than 5%.	None
4x4 matrix	It should be less than 9%.	Functionality, Reliability, Usability, Portability
5x5 and larger matrix	It should be less than 10%.	Comparison of Main Factors, Maintainability

The CR does not exceed 10% of the comparison matrix of main quality factors and sub-factors of maintainability. The CR ratio of the sub-factors of *functionality*, *reliability*, *usability*, *portability* is less than 9%. For the remaining comparison items such as *efficiency*, *elasticity*, *p olicy& legal requirements/obligations*, *customer service*, the consistency ratio cannot be calculated, since they only have two items (sub-quality factors) to be prioritized. According to the algorithm of the consistency ratio calculation, at least three items should be prioritized.

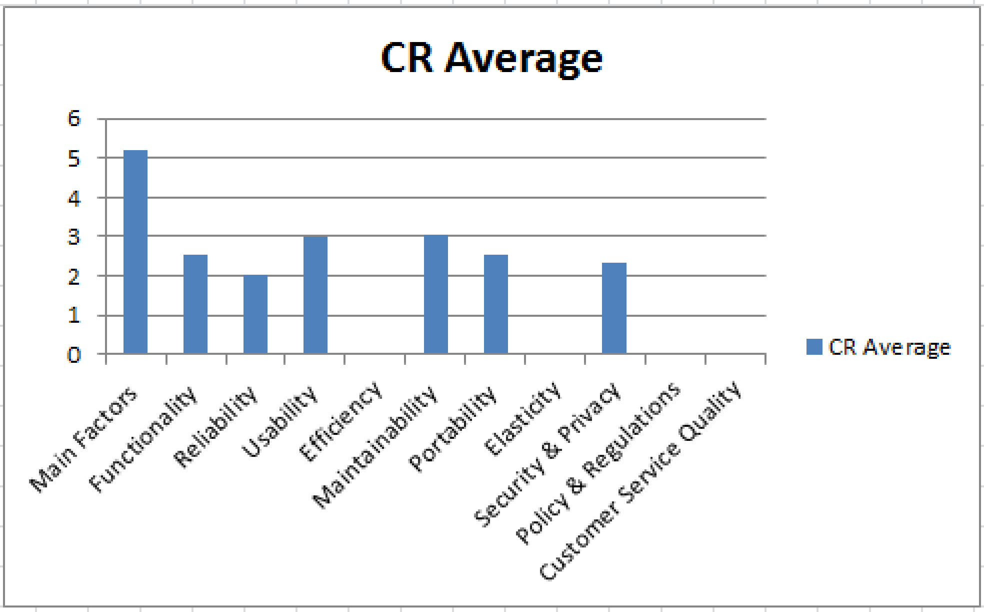

Figure 12: Consistency Ratio of Each Comparison Item

In this study, the average CR of each comparison item is less than 6% (See Figure 12). As a result, there is no unreliable response, and the survey responses are consistent.

5.7 Weight Calculation and Normalization

Having checked the consistency ratio as stated in Section 5.6, the local weights of all factors are calculated. However, the local weight itself cannot show the comparison among all factors within the sub-level factors to ascertain the concealed meaning behind the scene. Thus, the global weight of the each sub-factor should be calculated as the multiplication of the local weight by its parent's weight.

As seen from Table 23, the local weights of Availability (0.317) and Stability (0.318) have almost same value; however, the weights of their parents are significantly different. While the weight of the parent factor of "Availability (i.e., Reliability) is equal to 0.163, the weight of the parent factor of Stability (i.e., Maintainability) is equal to 0.087. Consequently, the global weights of Availability and Stability are calculated as 0.052 and 0.028 respectively, and availability has almost twice perceived importance over stability. Besides, Availability is the second important factor while Stability is the sixth important factor amongst the main quality factors. Therefore, the global weights should be considered for the ranking factors within the research model. Finally, the normalization of the weights is conducted.

Table 23: The Weights of the Quality Factors

Quality Factors	Weights	Priority	Sub-quality Factors	Local Weights	Local Priority	Global Weights	Normalized (%)	Global Priority
Functionality	0.119	3	Suitability	0.246	2	0.029	%3	4
			Interoperability	0.173	4	0.021	%2	5
			Accuracy	0.320	1	0.038	%4	3
			Ease of Access	0.261	3	0.031	%3	4
Reliability	0.163	2	Maturity	0.205	4	0.033	%3	4
			Fault Tolerance	0.227	3	0.037	%4	3
			Recoverability	0.251	2	0.041	%4	3
			Availability	0.317	1	0.052	%5	2
Usability	0.094	4	Understandability	0.354	1	0.033	%3	4
			Learnability	0.246	3	0.023	%2	5
			Operability	0.258	2	0.024	%2	5
			Attractiveness	0.143	4	0.013	%1	6
Efficiency	0.081	6	Time behavior	0.589	1	0.048	%5	2
			Resource behavior	0.411	2	0.033	%3	4
Maintainability	0.087	5	Analyzability	0.194	2	0.017	%1	6
			Changeability	0.183	3	0.016	%2	5
			Stability	0.318	1	0.028	%3	4
			Testability	0.157	4	0.014	%1	6
			Open Source Availability	0.148	5	0.013	%1	6
Portability	0.064	10	Adaptability	0.307	1	0.020	%2	5
			Install ability	0.222	4	0.014	%1	6
			Co-existence	0.238	2	0.015	%2	5
			Replace-ability	0.232	3	0.015	%2	5
Elasticity	0.070	9	Multi-client access adjustment	0.510	1	0.036	%4	3
			Resource allocation adjustment	0.490	2	0.035	%4	3
Security & Privacy	0.172	1	Authorization	0.283	2	0.049	%5	2
			Audit	0.202	3	0.035	%4	3
			Protection	0.330	1	0.057	%6	1
			Multi-location Issues	0.185	4	0.032	%3	4
Policy & Regulations	0.077	7	Compliance	0.537	1	0.041	%4	3
			Legal Requirements/ Obligations	0.463	2	0.036	%4	3
Customer Service Quality	0.072	8	Technical support	0.604	1	0.044	%4	3
			Customer support	0.396	2	0.029	%3	4

This research shows following substantial outcomes:

- The most significant quality factors are determined as “security & privacy”, “reliability”, “functionality”,” usability”, and “maintainability”.
- “Security & Privacy” has been found as the most significant quality factor. That means, providers of Cloud-EIS should have a high level of security and privacy to resolve security concerns of the enterprises with respect to the cloud environment, and to appeal/encourage them to implement cloud-based enterprise solutions. Furthermore, perceived trust towards cloud provider

should be enhanced as well. A cloud provider can arrange the enterprise-specific SLA, and get continuous feedback from the client organization. Thus, it will provide an atmosphere of trust, and reduce concerns related to security of Cloud-EIS.

- Protection is the most significant quality factor amongst other sub-quality factors. In other words, enterprises are concerned about their private data protection from any damage or harmful attack as well as the security of their network system.
- Reliability is the second significant quality factor amongst the other factors. That means, the capability of maintaining the service level of Cloud-EIS is a significant dimension for businesses. The percentage of the system uptime, recoverability of the system once the system is failed, the way of handling errors, and the performance of the fault elimination over time are concerned as a reliability problem that enterprises face. A cloud provider should satisfy the reliability requirements stated in SLA in order to convince and appeal more enterprises to implement their Cloud-EIS product.
- Functionality is found as the third significant quality factor. That means, the functional capability of Cloud-EIS application is a significant dimension to select the suitable cloud product. The ability to perform all tasks required by client organizations, and the capability of modification (e.g., changing the user interface, the addition of another language and adding automation routines, etc.) according to organizational/ personal preferences profoundly affect the implementation decision of the corresponding Cloud-EIS product. Therefore, the Cloud-EIS product should satisfy customer specifications related to the functional capability.
- Usability of Cloud-EIS is another important quality factor. If the users easily understand and learn how to use and operate the corresponding Cloud-EIS product, the enterprise will be more enthusiastic to implement such product. As Oliveira et al. (2014) stated, usability is a significant issue for the enterprises that lack IT specialists with advanced technological skills. If the usability level of Cloud-EIS product is unsatisfactory, much more effort can be needed or the personnel with a high level of IT skills can be required for utilizing the product; yet this is not a desired situation for enterprises.
- Maintainability of Cloud-EIS is found as another substantial quality factor. Since the ability of the correction/modification of the functional specifications of Cloud-EIS product provides continuous improvements in overall system, and the number of available APIs in the product affects the maintenance operations with respect to sustainability of the product, it is seen as a significant quality factor.
- Efficiency, Policy and Regulations, Customer Service Quality, Elasticity and Portability are the most insignificant quality factors. Although these five factors affect the quality of Cloud-EIS, these factors have relatively smaller weights than the others. It can be concluded that enterprises can omit these factors if other quality aspects (e.g., high level of security and privacy, functionality fitness, etc.) meet the specifications of client organizations.
- Portability is found as the most insignificant quality factor. The capability of moving from one environment to another is not seen as a substantial quality factor for the enterprise usage of Cloud-EIS. In other words, the ability to

move Cloud-EIS services/data from one provider to another one is not so vital for the quality of Cloud-EIS. Cloud-EIS providers can assign lower priority to the portability of the system while designing their product.

5.8 Comparison of the Opinions between PhD Student and Experts

As stated in Section 5.3, the responders consist of 15 PhD students and 20 experts working with EIS in a company. Since the sample size is relatively small, and the data of the population are without outliers, and consists of the two independent samples, Mann-Whitney U Test which is a kind of non-parametric statistical test is suitable to conduct a hypothesis test whether there is a significant difference between the rankings of two sampling.

The hypotheses of Mann-Whitney U Test are stated as follows: the null hypothesis is that there is no significant difference between the ranking of two sampling ($\mu 1 = \mu 2$), whereas the alternative hypothesis states that there is a significant difference between the ranking of the two groups ($\mu 1 \neq \mu 2$). The hypotheses are stated as follows:

$$H_0: \mu 1 = \mu 2$$

$$H_a: \mu 1 \neq \mu 2$$

Accordingly, Mann-Whitney U Test is performed in Ms Excel. As seen from Figure 13, P-value is approximately equal to 0.41, and it is greater than 0.05 which is the threshold value. That means the null hypothesis (H_0) is accepted. It is concluded that there is no significant difference between the ranking results of PhD students and Experts. In other words, the responders have reached consensus on which factors are the most significant factors amongst others.

	PhD Students	*Experts*
Mean	10.2	10.8
Standard Error	1.804623691	2.025120024
Median	9.5	12.5
Standard Deviation	5.706721184	6.403991811
Sample Variance	32.56666667	41.01111111
Kurtosis	-1.108012059	-1.130451246
Skewness	0.404158999	-0.326927329
Range	16.5	18.5
Minimum	3	1
Maximum	19.5	19.5
Sum	102	108
Count	10	10
Confidence Level(95.0%)	4.082342409	4.581139768
Rank Sum	102.00	108.00
U	47.00	53.00
min U	47.00	
mu	50	
sigma	13.22875656	
P-value=	0.41029792	
T Test P=	0.827461927	

Figure 13: Mann-Whitney U Test Results

As a result of the Mann-Whitney U Test, there is no significant difference between the ranking results of PhD students and Experts. However, a detailed analysis can be conducted by considering local and global weights of each factor resulting from the AHP survey separately. For this aim, Table 24 is constructed.

Table 24: Comparison of the Opinions between PhD Student and Experts

	Weights		**Priority**			**Local weights**		**Global weights**	
Quality Factors	**PhD students**	**Experts**	**PhD Students**	**Experts**	**Sub-quality Factors**	**PhD students**	**Experts**	**PhD students**	**Experts**
Functionality	0.125	0.115	3	3	Suitability	0.296	0.208	0.037	0.024
					Interoperability	0.162	0.182	0.020	0.021
					Accuracy	0.363	0.287	0.045	0.033
					Ease of Access	0.178	0.324	0.022	0.037
Reliability	0.162	0.164	1	2	Maturity	0.241	0.178	0.039	0.029
					Fault Tolerance	0.204	0.245	0.033	0.040
					Recoverability	0.203	0.287	0.033	0.047
					Availability	0.353	0.290	0.061	0.047
Usability	0.081	0.104	7	4	Understandability	0.372	0.340	0.030	0.035
					Learnability	0.250	0.243	0.020	0.025
					Operability	0.242	0.270	0.019	0.028
					Attractiveness	0.137	0.147	0.011	0.015
Efficiency	0.099	0.068	5	9	Time behavior	0.567	0.605	0.056	0.041
					Resource behavior	0.433	0.395	0.043	0.027
Maintainability	0.104	0.075	4	5	Analyzability	0.221	0.173	0.023	0.013
					Changeability	0.173	0.191	0.018	0.014
					Stability	0.324	0.313	0.034	0.023
					Testability	0.143	0.167	0.015	0.012
					Open Source Availability	0.139	0.156	0.014	0.012
Portability	0.064	0.064	10	10	Adaptability	0.340	0.283	0.022	0.018
					Install ability	0.213	0.230	0.014	0.015
					Co-existence	0.222	0.250	0.014	0.016
					Replace-ability	0.225	0.238	0.014	0.015
Elasticity	0.069	0.072	9	8	Multi-client access adjustment	0.434	0.538	0.030	0.039
					Resource allocation adjustment	0.506	0.463	0.035	0.033
Security & Privacy	0.144	0.192	2	1	Authorization	0.333	0.245	0.048	0.047
					Audit	0.199	0.205	0.029	0.039
					Protection	0.296	0.356	0.043	0.068
					Multi-location Issues	0.172	0.194	0.025	0.037
Policy& Regulations	0.083	0.073	6	7	Compliance	0.582	0.503	0.048	0.037
					Legal Requirements/ Obligations	0.418	0.497	0.035	0.036
Customer Service Quality	0.071	0.074	8	6	Technical support	0.670	0.555	0.047	0.041
					Customer support	0.330	0.446	0.023	0.033

Table 24 shows the following substantial outcomes:

- Both PhD students and Experts have defined Security & Privacy, Reliability, and Functionality as top three significant quality factors of Cloud-EIS. However, according to PhD students, Reliability is slightly more important than Security & Privacy, while Experts prioritize Security & Privacy over Reliability.
- PhD students have defined that Accuracy is the most significant sub-factor of Functionality, whereas Experts have given much more weight on Ease of Access amongst the other sub-factors. Experts point out that access requirement such as minimum required connection speed, or the number of supported platforms by the Cloud-EIS product is slightly more important sub-quality factor than the accuracy of the application.
- According to PhD students, Resource Allocation Adjustment is more important than Multi-client Access Adjustment. However, Experts state that sharing resources among many clients with a specified level of performance has much more effect on the quality rather than resource allocation.
- According to Experts, Protection, Availability and Recoverability are found as the most significant sub-quality factors, while PhD students defines the most significant sub-quality factors as follows: Availability, Time Efficiency, and Authorization. Availability is seen as the most significant quality factor by two sampling groups.
- PhD students and Experts have reached on consensus that portability is the most insignificant factor that affects the quality of Cloud-EIS.

CHAPTER 6

ILLUSTRATION of the QUALITY EVALUATION

In this chapter, the illustration of the quality evalution is provided by comparing XAP Logistics and Shipping Management (2016) and SAP Business ByDesign Cloud ERP (2016). According to the metric values of these products provided in Chapter 4, and the weights of the quality factors obtained from the AHP survey as given in Chapter 5, the following Table 25, Table 26 and Table 27 are constructed.

Table 25: Comparison of the Two Cloud-EIS Products (Part 1)

Quality Factors	**Sub-factors**	**Metrics**	**Metric Value (XAP)**	**Metric Value (SAP)**	**Better Product based on Metric**	**Better Product based on Sub-factor**
Functionality	Suitability	Functional Suitability	0	1	SAP	SAP, XAP
		Customization	35 API	34 API	XAP	
	Ease of Access	Min connection speed	1Mb	1Mb	XAP, SAP	XAP
		OS supportability	5/6	3/6	XAP	
		Supported Platforms	3/3	3/3	XAP, SAP	
		Offline access	1	1	XAP, SAP	
Reliability	Availability	System uptime	0.999	0.999	XAP, SAP	XAP, SAP
Usability	Its Sub-factors	Its metrics	NA	NA		
Maintain-ability	Open Source Availability	Open source	1	0	XAP, SAP	XAP, SAP

Table 26: Comparison of the Two Cloud-EIS Products (Part 2)

Quality Factors	**Sub-factors**	**Metrics**	**Metric Value (XAP)**	**Metric Value (SAP)**	**Better Product based on Metric**	**Better Product based on Sub-factor**
Efficiency	Time Behavior	Response time	1000 ms	500 ms	SAP	SAP
	Resource Behavior	Min Ram	8 GB	2 GB	SAP	XAP
		Min CPU	2.0 GHz	2.4 GHz	XAP	
		Min memory	25 GB	30 GB	XAP	
Portability	Replace ability	Migration support	1	1	XAP, SAP	XAP, SAP
		Data export capability	1	1	XAP, SAP	
		System setting configuration	15 min	15 min	XAP, SAP	
Elasticity	Multi-client Access Adjustment	Maximum instances per VM	500 instances	28000 instances	SAP	SAP
		Max number of users	4000	200+	SAP	
	Resource Allocation Adjustment	Time devoted to the scaling operation	NA	60 seconds	XAP, SAP	XAP, SAP
		Allocated memory per client	[32GB, 64GB]	NA	XAP, SAP	
Security & Privacy	Authorization	Authorization Metrics	1	1	XAP, SAP	XAP, SAP
	Audit	Audit Metrics	1	1	XAP, SAP	
	Protection	Protection Metrics	1	1	XAP, SAP	
	Multi-location Issues	Multi-location Issues Metrics	1	1	XAP, SAP	

Table 27: Comparison of the Two Cloud-EIS Products (Part 3)

Quality Factors	**Sub-factors**	**Metrics**	**Metric Value (XAP)**	**Metric Value (SAP)**	**Better Product based on Metric**	**Better Product based on Sub-factor**
Policy & Regulations	Compliance	Compliance	1	1	XAP, SAP	XAP, SAP
	Legal requirements/ Obligations	Legal requirements/ Obligations	1	1	XAP, SAP	
Customer Service Quality	Customer Support	Working Hours	7x24	7x24	XAP, SAP	SAP
		Incident Priority	1	1	XAP, SAP	
		Communication Channels	4/4	4/4	XAP, SAP	
		Response time for a help request	[2 hours, 4 days]	[1hours, 3 days]	SAP	
	Technical Support	Time dedicated to fixing a technical problem	[2 days, 30 days]	[14 days, 45days]	XAP	XAP

As seen from Table 25, Table 26, and Table 27, there are some Not Applicable (NA) values. As explained in Chapter 4, since the metrics " usability" requires more systematic approach such SUS instrument which is seen as out of the scope of this study, the metrics of the usability are stated as NA. Similarly, the metrics of "time devoted to the scaling operation" for XAP, and the metric value of "allocated memory per client" for SAP are stated as NA, since the metric values of the corresponding product are not obtained. Therefore, the comparison of the product cannot be conducted with NA values. It is assumed that these two products have an equal quality level with respect to "resource allocation adjustment" metric. Although there are NA values, these tables still provide a comparison of the products with respect to each quality factor.

In order to compare these two products the following Table 28 is constructed. In the table, Quality Index (QI) is expressed as a binary value, which are defined as follows:

"1" represents the superior/equal product from the comparison pair,

"0" represents the inferior product from the comparison pair.

As for the NA values of the usability metrics, it is assumed that both products have the same level of the usability. However, it is excluded from the evaluation. Therefore, the QI of each product is stated as “0”.

Table 28: Overall Comparison of Two Products

Quality Factors	Weights	Sub-quality Factors	Local Weights	QI (XAP)	QI (SAP)	Weighted QI (XAP)	Weighted QI (SAP)
Functionality	0.119	Suitability	0.246	0	1	0.261	0.246
		Interoperability	0.173	0	0		
		Accuracy	0.320	0	0		
		Ease of Access	0.261	1	0		
Reliability	0.163	Maturity	0.205	0	0	0.317	0.317
		Fault Tolerance	0.227	0	0		
		Recoverability	0.251	0	0		
		Availability	0.317	1	1		
Usability	0.094	Understandability	0.354	0	0	0	0
		Learnability	0.246	0	0		
		Operability	0.258	0	0		
		Attractiveness	0.143	0	0		
Efficiency	0.081	Time behavior	0.589	0	1	0.411	0.589
		Resource behavior	0.411	1	0		
Maintainability	0.087	Analyzability	0.194	0	0	0.148	0.148
		Changeability	0.183	0	0		
		Stability	0.318	0	0		
		Testability	0.157	0	0		
		Open Source Availability	0.148	1	1		
Portability	0.064	Adaptability	0.307	0	0	0.232	0.232
		Install ability	0.222	0	0		
		Co-existence	0.238	0	0		
		Replace-ability	0.232	1	1		
Elasticity	0.070	Multi-client access adjustment	0.510	0	1	0.490	1.000
		Resource allocation adjustment	0.490	1	1		
Security & Privacy	0.172	Authorization	0.283	1	1	1.000	1.000
		Audit	0.202	1	1		
		Protection	0.330	1	1		
		Multi-location Issues	0.185	1	1		
Policy & Regulations	0.077	Compliance	0.537	1	1	1.000	1.000
		Legal Requirements/ Obligations	0.463	1	1		
Customer Service Quality	0.072	Technical support	0.604	1	0	0.604	0.396
		Customer support	0.396	0	1		

Table 28 is constructed for the aim of calculating the Weighted Quality Index (WQI) of each product according to the weights of the sub-quality and sub-quality factors. Weighted QI is calculated as the multiplication of the corresponding product QI value by local weight of the corresponding sub-quality factor as illustrated below:

$$Weighted\_QI_n = \sum_{m=1}^{m} (local\_weight_m \; x \; sub\_QI_m)$$

where $local\_weight_m$ is the local weight of the m th sub-quality factor, sub_QI_m is the product quality index for the m th sub-quality factor, m is the m th sub-quality factor, n is the n th quality factor, where $1 \leq n \leq 10$.

According to Table 28, the elasticity of the services provided by SAP has more powerful than XAP, since SAP provides 28000 threads as maximum instances per VM, while XAP provides only 5000 instances per VM.

Total Quality Index (TQI) of these two products can be calculated as the multiplication of the corresponding main quality factor weights by Weighted QI value as stated follows:

$$\mathrm{TQI} = \sum_{n=1}^{10} (\mathrm{quality\_factor_n \; x \; Weighted\_QI_n})$$

where n is the n th quality factor, $1 \leq n \leq 10$,

$quality\_factor_n$ is the weight of the n th quality factor,

$Weighted\_QI_n$ is the weighted quality index of the n th quality factor.

The TQI of the XAP product (TQI_{XAP}) can be calculated as follows:

(0.119 x 0.261) + (0.163 x 0.317) + (0.094x 0) + (0.081x 0.411) + (0.087x 0.148) + (0.064x 0.232) + (0.070x 0.490) + (0.172x 1) + (0.077x 1) + (0.072x 0.604) = 0.471

The TQI of the SAP product (TQI_{SAP}) can be calculated as follows:

(0.119 x 0.246) + (0.163 x 0.317) + (0.094x 0) + (0.081x 0.589) + (0.087x0.148) + (0.064x 0.232) + (0.070x 1.000) + (0.172x 1.000) + (0.077x 1.000) + (0.072x 0.396) = 0.504

As a result, the quality index of SAP product is greater than the quality index of the XAP product ($TQI_{SAP} > TQI_{XAP}$).

As illustrated in this example, this analysis can be considered as a quality assessment tool that supports enterprises in making business decisions on selecting the appropriate product from the alternatives. According to this comparison example, SAP product is found as a better alternative solution rather than XAP product. However, the organizational preferences of the company may affect the decision of the selection. Since SAP is a commercial business suite, the organization may prefer to implement an open source application such as XAP. Therefore, the comparison criteria can be changed according to the constraints of business, and this will affect the result of the analysis illustrated.

CHAPTER 7

CONCLUSION

In this study, it is aimed to investigate the quality of Cloud-EIS. First of all, this study presents a literature review of the existing quality models including software quality models, service quality models, and cloud-related quality. As a consequence of the extensive review, Table 2, and Table 3 are constructed for tracing available quality factors, and their frequency of occurrence in different quality models. Subsequently, Table 4 is constructed in order to analyze existing cloud-related quality models in detail.

Secondly, the proposed quality factors of the quality model of Cloud-EIS, and their definitions are given in Table 6, and similarly the proposed sub-quality factors, and their definitions are listed in Table 7. Consequently, the quality model of Cloud-EIS is developed as depicted in Figure 4. After constructing the quality model, the metrics of each quality factor (KPIs) are formalized, and provided in the metric tables; together with the metric name, the purpose of the metric, computation method, interpretation of measured value, metric scale type, and measure type.

Consequently, the Analytic Hierarchy Process (AHP) is employed in order to rank the quality factors of Cloud-EIS. The results of the AHP survey are given in Table 22, and Table 23. Accordingly, the findings of the survey are provided, and discussed in terms of the significance of each quality factor of the proposed quality model.

At the final stage of the study, the illustration of the proposed assessment method is explained by comparing of two Cloud-EIS products based on the weights of the quality and sub-quality factors and corresponding metric values of the products.

As a main contribution, this study proposes a comprehensive and hierarchically-structured quality model of Cloud-EIS, which concerns not only the service quality but also the software quality (IT features) of Cloud-EIS products. Consequently, the quality model consists of 10 main quality factors of Cloud-EIS, which are determined as follows: functionality, reliability, usability, efficiency, maintainability, portability, security & privacy, policy and regulations, elasticity, and customer service quality. Accordingly, each quality factor is divided into sub-quality factors, and in total 33 sub-quality factors are determined as seen from Figure 4. Although the quality model is developed for enterprise usage, it is also applicable for cloud services in general.

Another main contribution of this study is that it proposes a set of metrics, which provides a systematic quality assessment for diagnosing the quality of Cloud-EIS products. Consequently, three Cloud-EIS products which are SAP Business ByDesign, Gigaspaces XAP, and OwnCloud are selected to show the applicability of the metrics of the quality model of Cloud-EIS. Hence, enterprises can employ the quality assessment method provided in this study as a tool to diagnose the quality of the corresponding Cloud-EIS product.

Additionally, the ranking of the quality factors of Cloud-EIS is performed by a survey designed with the AHP method. The results show that the most significant quality factors of Cloud-EIS are determined as security & privacy, reliability, functionality, usability, and maintainability. Furthermore, the AHP survey findings are interpreted in order to provide enterprises and cloud providers some insight on the importance of each quality factor of Cloud-EIS. The findings also present a guideline to Cloud-EIS providers on how to design their products in order to increase customer satisfaction, and to appeal more customers.

Lastly, Mann-Whitney U Test is conducted on the ranking results of PhD students and Experts in order to understand whether there is a significant difference between the responses of these two sampling groups. The test results show that the responders have reached truly consensus on which quality factors are the most significant amongst others.

Future Work

Due to the subjective nature of “usability” quality factor, usability metrics requires a comprehensive and systematic analysis, such as System Usability Scale (SUS) instrument. Since SUS-based test is out of scope of this study, the usability of Cloud-EIS is planned to be investigated as a future research study. Similarly, some of the sub-quality factors of Cloud-EIS has not applicable (NA) values. Because the corresponding metric value calculation needs long-term observations on the corresponding event occurrence in a specified period of time (e.g., Frequency of network failure, the number of faults eliminated over time, etc.). Therefore, the applicability of these metrics is intended to be studied in future work.

Secondly, it is planned to conduct a survey among the enterprises that implement one of the cloud-based logistics products from the following companies: Gigaspaces, SAP, and Owncloud. Consequently, the survey results will be discussed by considering the quality evaluation of these three products provided in this study.

Thirdly, a case study of group decision making on selecting the suitable Cloud-EIS product will be conducted by employing the AHP method among the experts in an enterprise intending to implement Cloud-EIS product.

Finally, our initial findings are compatible with the standard “ISO/IEC 25010:2011Systems and Software Engineering: Systems and Software Quality Requirements and Evaluation (SQuaRE)”, and the quality model will be modified by considering this newer standard, which provides “a quality in use model” and “a product quality model” for products.

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APPENDIX A

Detailed Explanation of Metric Scale Types and Measurement Types

These explanations are reproduced from the document of the “ISO/IEC TR 9126-2 Software engineering –Product quality – Part 2: External metrics (2002)”.

1. Metric Scale Types

Metric scale types are: Nominal scale, Ordinal scale, Interval scale, Ratio scale, and Absolute scale. A scale should always be defined as M'=F(M), where F is the admissible function. Also the description of each measurement scale type contains a description of the admissible function (if M is a metric then M'=F(M) is also a metric).

(a) Nominal Scale

M'=F(M) where F is any one-to-one mapping.

This includes classification, for example, software fault types (data, control, other). An average has a meaning only if it is calculated with frequency of the same type. A ratio has a meaning only when it is calculated with frequency of each mapped type. Therefore, the ratio and average may be used to represent a difference in frequency of only the same type between early and later cases or two similar cases. Otherwise, they may be used to mutually compare the frequency of each other type respectively.

Examples: Town transport line identification number, Compiler error message identification number

Meaningful statements are Numbers of different categories only.

(b) Ordinal Scale

M'=F (M) where F is any monotonic increasing mapping that is, M(x)>=M(y) implies M'(x)>=M'(y).

This includes ordering, for example, software failure by severity (negligible, marginal, critical, and catastrophic). An average has a meaning only if it is calculated with frequency of the same mapped order. A ratio has a meaning only when it is calculated with the frequency of each mapped order. Therefore, the ratio and the average may be used to represent a difference in frequency of only the same order between early and later cases or two similar cases. Otherwise, they may be used to compare mutually the frequency of each order.

Examples: School exam results (excellent, good, acceptable, not acceptable),

Meaningful statements: Each will depend on its position in the order , for example the median.

(c) Interval Scale

M'=aM+b (a>0)

This includes ordered rating scales where the difference between two measures has an empirical meaning. However the ratio of two measures in an interval scale may not have the same empirical meaning.

Examples: Temperature (Celsius, Fahrenheit, Kalvin), difference between the actual computation time and the time predicted

Meaningful statements: An arithmetic average and anything that depends on an order

(d) Ratio Scale

M'=aM (a>0)

This includes ordered rating scales,where the difference between two measures and also the proportion of two measures have the same empirical meaning. An average and a ratio have meaning respectively and they give actual meaning to the values.

Examples: Length, Weight, Time, Size, Count

Meaningful statements: Geometrical mean, Percentage

(e) Absolute Scale

M'=M they can be measured only in one way.

Any statement relating to measures is meaningful. For example, the result of dividing one ratio scale type measure by another ratio scale type measure where the unit of measurement is the same is absolute. An absolute scale type measurement is in fact one without any unit.

Example: Number of lines of code with comments divided by the total lines of code

Meaningful statements: Everything

2. Measurement Types

Measurements types can be Size type (e.g. Function size), Time type (e.g. Processing time), Count Type (e.g. Number of supported platforms of the software).

APPENDIX B

The AHP Survey Template

In this section, the screenshots of the AHP Survey Template are provided. First of all the instruction of the AHP Survey is provided in Figure 14. In Figure 15, an example (priorities for renting a new touring bike) that explains how to rate factors according to the scale is provided. Consequently, the comparison matrix of the main quality factors of the Cloud-EIS is provided in Figure 15. The comparison matrix of the functionality, reliability, usability, efficiency, maintainability, portability, elasticity, security& privacy, policy & regulations, and customer service quality are provided in Figure 17- Figure 26. Finally, the appendix of the AHP Survey is given in Figure 27, and Figure 28.

Dear Sir/Madam,

This survey has been designed to weighing quality factors of applications of Cloud-based Enterprise Information Systems by applying Analytic Hierachy Process (AHP). In our research, we have identified ten quality factors: *Functionality, Reliability, Usability, Efficiency, Maintainability, Portability, , Elasticity, Security and Privacy, Policy and Regulations and Customer Service Quality* . These quality factors are details into sub-characteristics of the main factors in the second level of the model. Your opinion helps us to determine the degree of the importance of them.

This survey has been divided into two parts; the goal of the first part is to obtain the strength of preference of quality factors and their sub-characteristics using *Pairwise Comparison* method.

Thank you for your time spent taking this survey.
Umut Şener

Part I

In each row of the given Matrix, which of the quality characteristics is more important with respect to the Cloud-based EIS applications? And how strongly? Work through the matrix comparing each of the factors to each other.Please select the related element from the drop-down list and use the 1-9 scale for your idea (1: Equal importance - 9 : Extreme importance).

Part II

In your opinion, what is the relative importance of the sub- characteristics of the main quality factors?Please identify your answer by the scale given. (1: Equal importance - 9 : Extreme importance)

Please see the Appendix A for the definition of the terms.

Analytic Hierarchy Process, AHP

1. Work through the matrix comparing each of the criteria to each other (pairwise comparisons)
2. For each comparison, decide which is the more important and select the appropriate weighting:

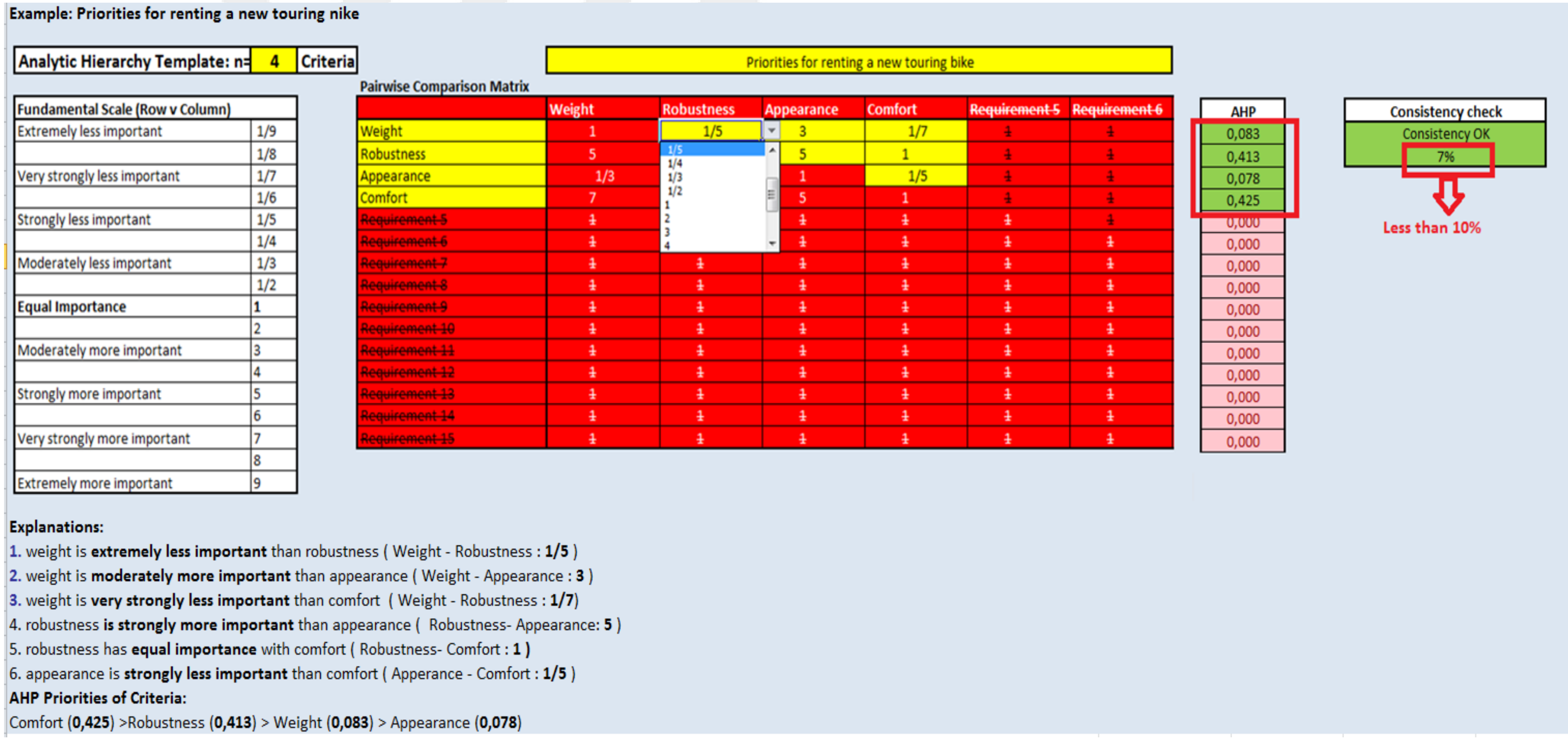
Increasing *column* importance over *row* ← Equal → Increasing *row* importance over *column*

1/9 1/8 1/7 1/6 1/5 1/4 1/3 1/2 1 2 3 4 5 6 7 8 9

3. Once completed the the AHP column contains the priorities for the given criteria
4. Check the consistency index which should be 10% or less
5. Please send us your comments, suggestions or problems - we appreciate your feedback

   Email: umut.snr@gmail.com

Figure 14: The Instruction of the AHP Survey



Example: Priorities for renting a new touring nike

Analytic Hierarchy Template: n=	4	Criteria

Priorities for renting a new touring bike

Fundamental Scale (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal Importance	1
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Weight	Robustness	Appearance	Comfort	~~Requirement 5~~	~~Requirement 6~~	AHP
Weight	1	1/5	3	1/7	~~1~~	~~1~~	0,083
Robustness	5		5	1	~~1~~	~~1~~	0,413
Appearance	1/3		1	1/5	~~1~~	~~1~~	0,078
Comfort	7		5	1	~~1~~	~~1~~	0,425
~~Requirement 5~~	~~1~~		~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 6~~	~~1~~		~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 7~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 8~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 9~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 10~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 11~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 12~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 13~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 14~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000
~~Requirement 15~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~	0,000

Consistency check
Consistency OK
7%

Explanations:

1. weight is **extremely less important** than robustness (Weight - Robustness : **1/5**)
2. weight is **moderately more important** than appearance (Weight - Appearance : **3**)
3. weight is **very strongly less important** than comfort (Weight - Robustness : **1/7**)
4. robustness **is strongly more important** than appearance (Robustness- Appearance: **5**)
5. robustness has **equal importance** with comfort (Robustness- Comfort : **1**)
6. appearance is **strongly less important** than comfort (Apperance - Comfort : **1/5**)

AHP Priorities of Criteria:

Comfort (**0,425**) >Robustness (**0,413**) > Weight (**0,083**) > Appearance (**0,078**)

Figure 15: The Example Provided in the Survey

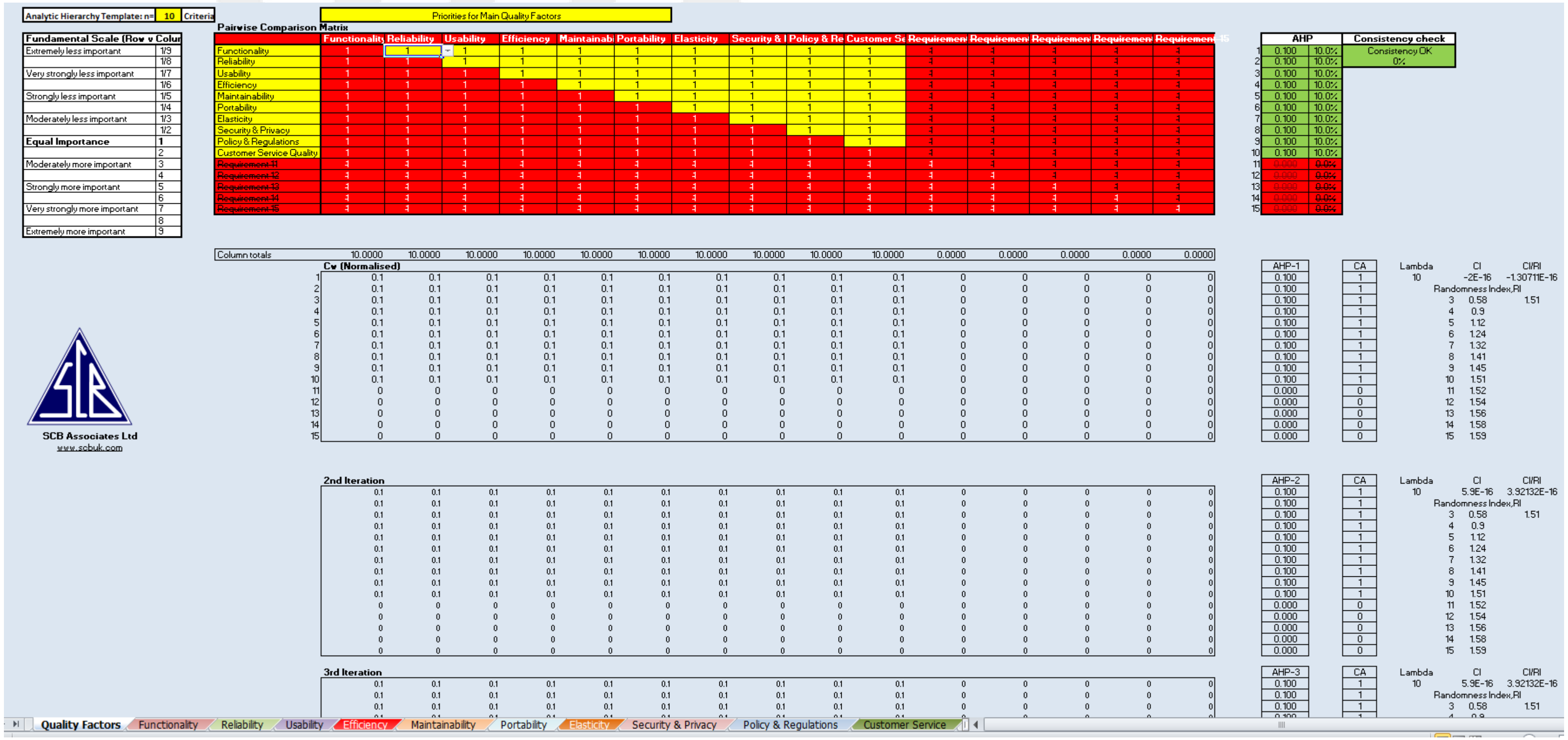


Figure 16: The comparison of the Main Quality Factors

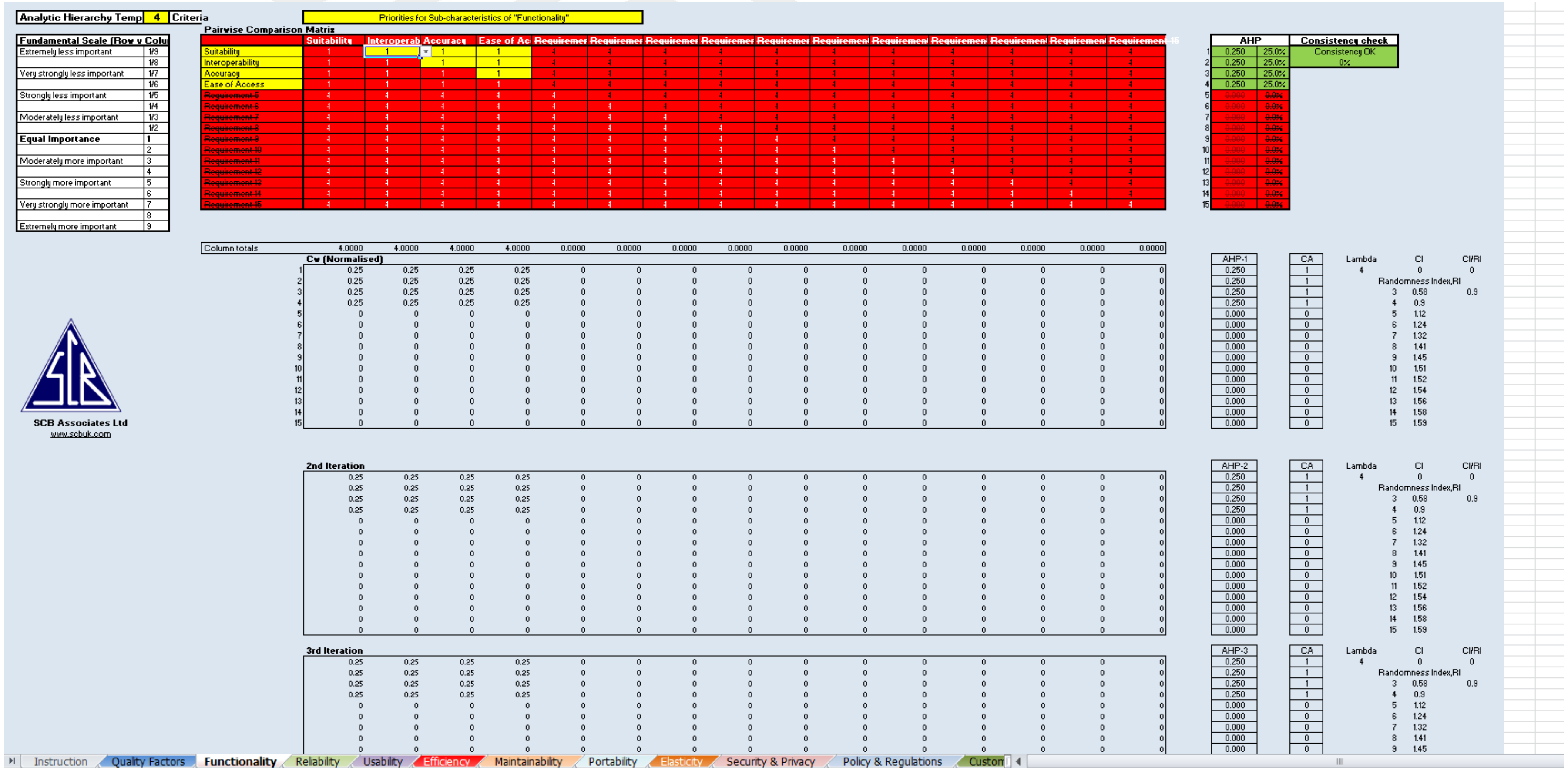


Figure 17: Functionality Matrix

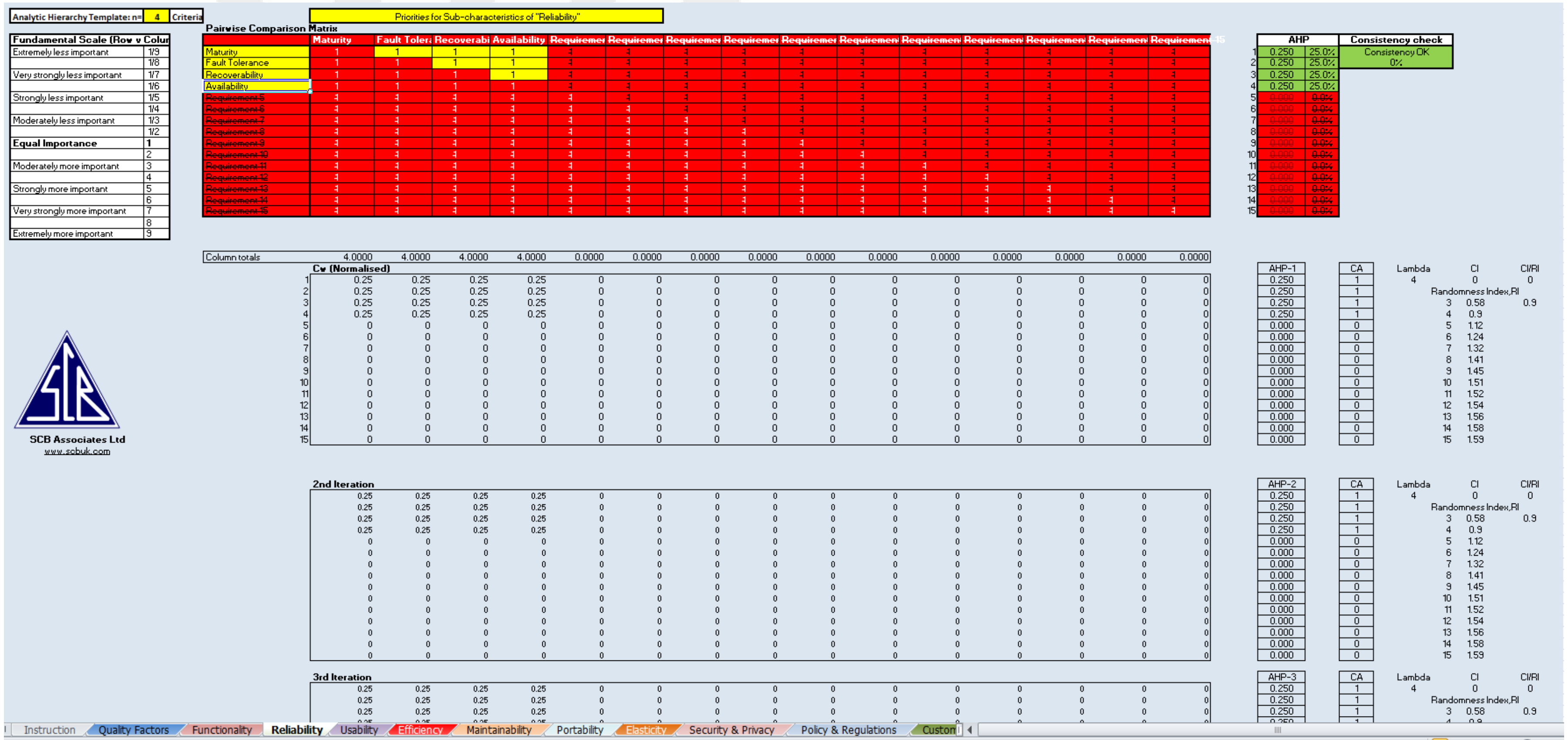


Figure 18: Reliability Matrix

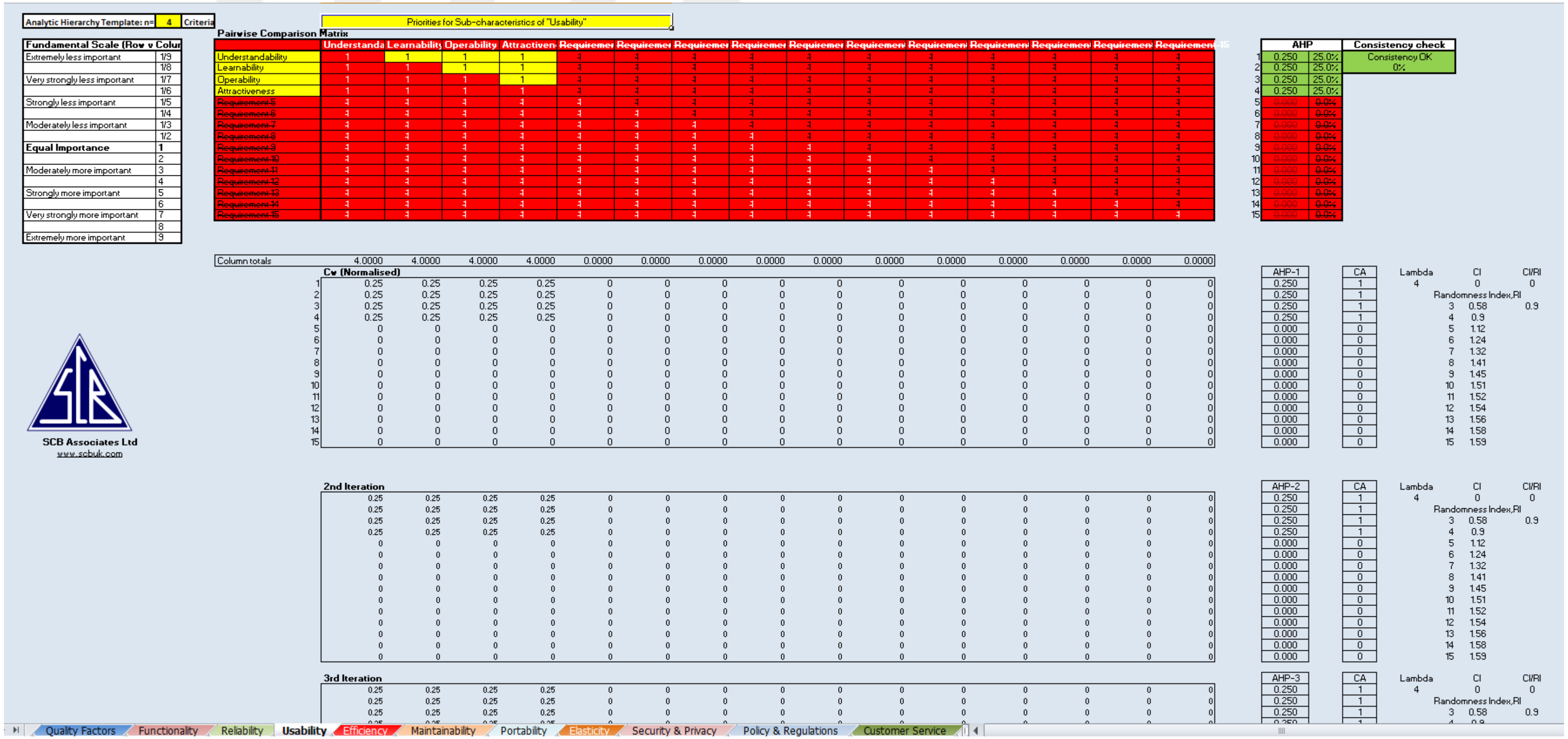


Figure 19: Usability Matrix

Analytic Hierachy Template n=	2	Criteria

Rate only TB over RB (into cell G5)

Fundamental Scale Row (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderatly less important	1/3
	1/2
Equal Importance	**1**
	2
Moderatly more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Resource behavior (RB)	Time behavior (TB)
Time behavior (TB)	1	1
Resource behavior (RB)	1	1

	AHP		Consistency check
1	0.50	50%	Consistency OK
2	0.50	50%	0%

Quality Factors | Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | Security & Privacy | Policy & Regulations | Customer Service

Figure 20: Efficiency Matrix

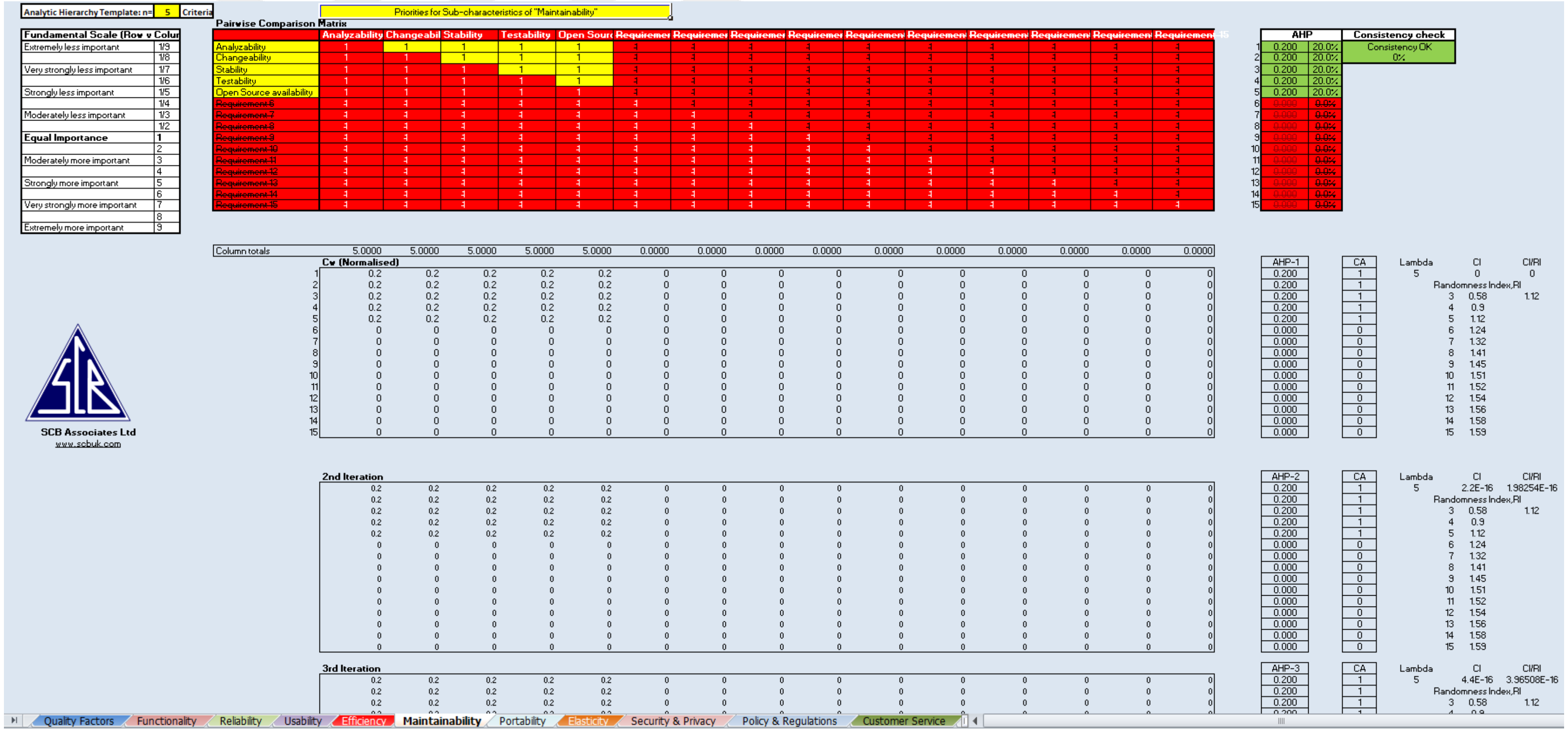


Figure 21: Maintainability Matrix

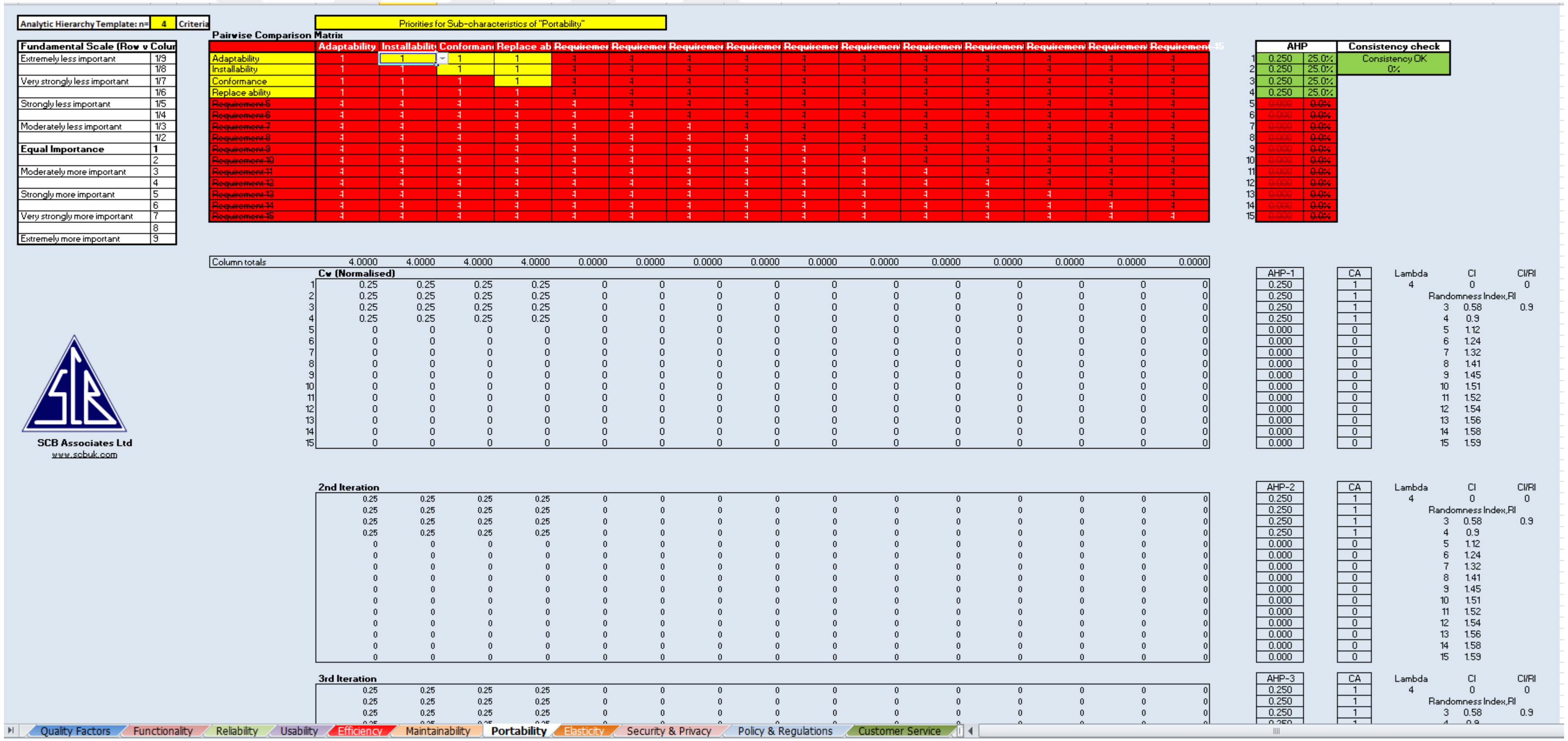


Figure 22: Portability Matrix

Analytic Hierachy Template n=	2	Criteria

Rate only TB over RB (into cell G5)

Fundamental Scale Row (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderatly less important	1/3
	1/2
Equal Importance	**1**
	2
Moderatly more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Resource allocation adjustment	Multi-client access adjustment
Multi-client access adjustment	1	1
Resource allocation adjustment	1	1

	AHP		Consistency check
1	0.50	50%	Consistency OK
2	0.50	50%	0%

Quality Factors | Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | Security & Privacy | Policy & Regulations | Customer Service

Figure 23: Elasticity Matrix

Analytic Hierarchy Template: n=	4	Criteria

Priorities for Sub-characteristics of "Security and Privacy"

Fundamental Scale (Row v Colur	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal Importance	**1**
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Authorizatio	Audit	Protection	Multi-locati	Requiremer	Requiremer	Requiremer	Requiremer	Requiremer	Requiremen	Requiremen	Requiremen	Requiremen	Requiremen	Requirement 15
Authorization	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Audit	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Protection	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Multi-location Issues	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 5~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 6~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 7~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 8~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 9~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 10~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 11~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 12~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 13~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 14~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
~~Requirement 15~~	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	AHP		Consistency check
1	0.250	25.0%	Consistency OK 0%
2	0.250	25.0%	
3	0.250	25.0%	
4	0.250	25.0%	
5	~~0.000~~	~~0.0%~~	
6	~~0.000~~	~~0.0%~~	
7	~~0.000~~	~~0.0%~~	
8	~~0.000~~	~~0.0%~~	
9	~~0.000~~	~~0.0%~~	
10	~~0.000~~	~~0.0%~~	
11	~~0.000~~	~~0.0%~~	
12	~~0.000~~	~~0.0%~~	
13	~~0.000~~	~~0.0%~~	
14	~~0.000~~	~~0.0%~~	
15	~~0.000~~	~~0.0%~~	

Column totals	4.0000	4.0000	4.0000	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Cw (Normalised)

																AHP-1	CA
1	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
2	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
3	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
4	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0

Lambda	CI	CI/RI
4	0	0

Randomness Index,RI		
3	0.58	0.9
4	0.9	
5	1.12	
6	1.24	
7	1.32	
8	1.41	
9	1.45	
10	1.51	
11	1.52	
12	1.54	
13	1.56	
14	1.58	
15	1.59	

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2nd Iteration

															AHP-2	CA
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0

Lambda	CI	CI/RI
4	0	0

Randomness Index,RI		
3	0.58	0.9
4	0.9	
5	1.12	
6	1.24	
7	1.32	
8	1.41	
9	1.45	
10	1.51	
11	1.52	
12	1.54	
13	1.56	
14	1.58	
15	1.59	

3rd Iteration

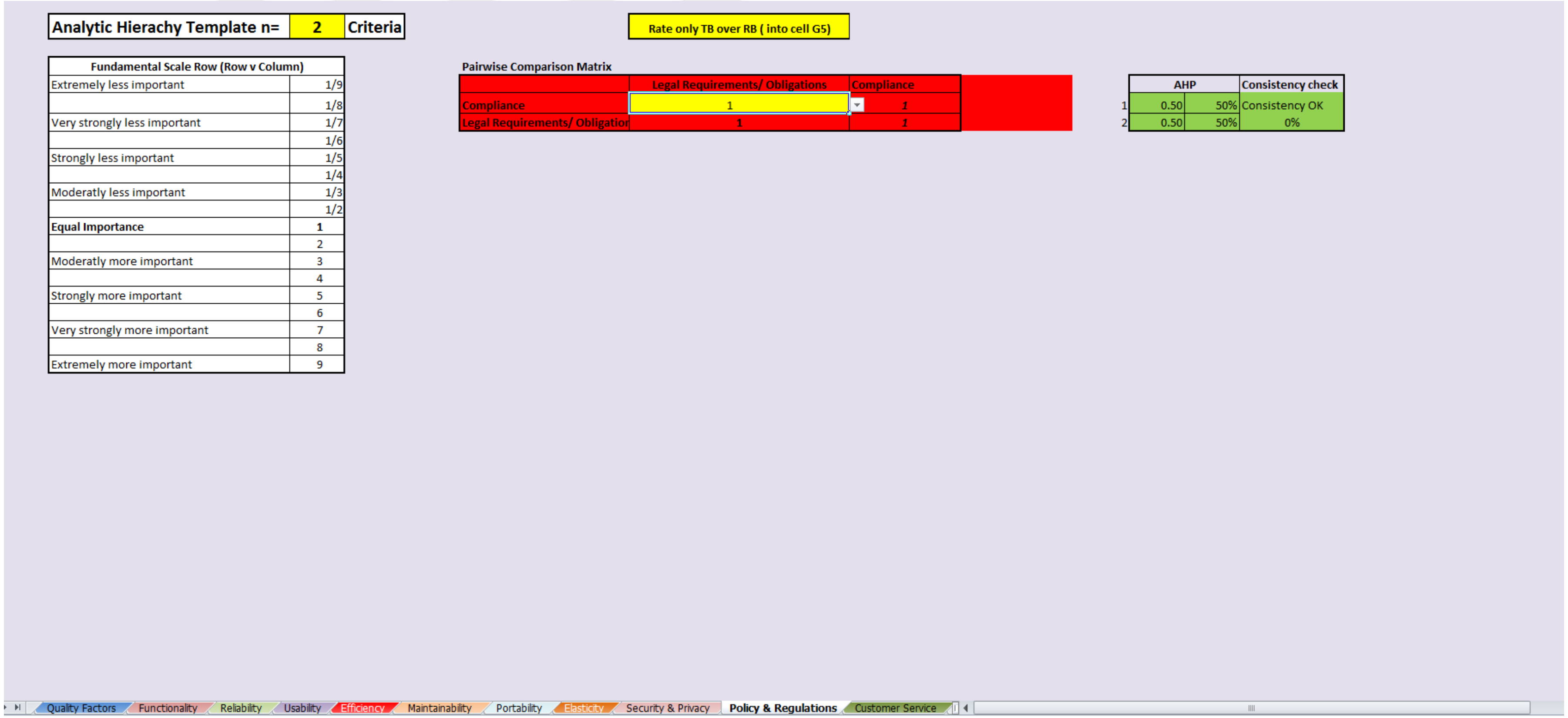
															AHP-3	CA
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1
0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0.250	1

Lambda	CI	CI/RI
4	0	0

Randomness Index,RI		
3	0.58	0.9

Quality Factors | Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | **Security & Privacy** | Policy & Regulations | Customer Service

Figure 24: Security & Privacy Matrix



Analytic Hierachy Template n=	2	Criteria

Rate only TB over RB (into cell G5)

Fundamental Scale Row (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderatly less important	1/3
	1/2
Equal Importance	**1**
	2
Moderatly more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Legal Requirements/ Obligations	Compliance
Compliance	1	*1*
Legal Requirements/ Obligatior	1	*1*

	AHP		Consistency check
1	0.50	50%	Consistency OK
2	0.50	50%	0%

Quality Factors | Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | Security & Privacy | **Policy & Regulations** | Customer Service

Figure 25: Policy& Regulations Matrix

Analytic Hierachy Template n=	2	Criteria

Rate only TB over RB (into cell G5)

Fundamental Scale Row (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderatly less important	1/3
	1/2
Equal Importance	**1**
	2
Moderatly more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Pairwise Comparison Matrix

	Customer support	Technical support
Technical support	1	*1*
Customer support	1	*1*

	AHP		Consistency check
1	0.50	50%	Consistency OK
2	0.50	50%	0%

Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | Security & Privacy | Policy & Regulations | **Customer Service** | Appendix A

Figure 26: Customer Service Quality Matrix

A. Functionality	A.1. Suitability	A.2. Interoperability	A.3. Accuracy	A.4. Customization	A.5. Ease of Access
"the capability of the software to provide functions which meet the stated and implied needs of users under specified conditions of usage (what the software does to meet needs)"	Can the software perform task required?	"the ability of diverse software systems to work together" Can the system interact with another system?	"the degree of correctness with which the results are produced" Is the result as expected?	How much a Cloud Service can be modified or builded according to individual or organization specifications or preference? Can user easily customise operation procedures for his/her convenience? What proportion of functions can be customised? user interface change or addition of another language or adding automation routines, etc.	What is the number of the supported platform/ available platform? What is the min connection speed required and bandwith to access cloud service?
B. Reliability	**B.1. Maturity**	**B.2. Fault Tolerance**	**B.3. Recoverability**	**B.3.1. Availability**	
the capability of the software product to maintain its level of performance under stated conditions for a stated period of time	Have most of the faults in the software been eliminated over time? (e.g., hard-drive or memory corruption)	Is the software capable of handling errors?	Can the software resume working & restore lost data after failure?	"the percentage of the system uptime"	
C. Usability	**C.1. Understandability**	**C.2. Learnability**	**C.3. Operability**	**C.4. Attractiveness**	
the capability of the software product to be understood, learned, used and provide visual appeal, under specified conditions of usage (the effort needed for use)	Does the user comprehend how to use the system easily?	Can the user learn to use the system easily?	Can the user use the system without much effort?	Does the interface look good?	
D. Efficiency	**D.1. Time Behavior**	**D.1. Resource Behavior**			
the capability of the software product to provide desired performance, relative to the amount of resources used, under stated conditions	How quickly does the system respond?	Does the system utilize resource efficiently? Is there any recommended resourse requirement to access cloud service ? (i.e., cpu,memory, bandwith)			
E. Maintainability	**E.1. Analyzability**	**E.2. Changeability**	**E.3. Stability**	**E.4. Testability**	**E.5. Open Source Availability**
the capability of the software product to be modified which may include corrections, improvements or adaptations of the software		Can the software be easily modified?	Can the software continue functioning if	Can the software be tested easily?	Is source code of the cloud based application available to the general public for use and/or

Functionality | Reliability | Usability | Efficiency | Maintainability | Portability | Elasticity | Security & Privacy | Policy & Regulations | Customer Service | Appendix A

Figure 27: The Appendix of the AHP Survey (Part 1)

9	**E. Maintainability**	**E.1. Analyzability**	**E.2. Changeability**	**E.3. Stability**	**E.4. Testability**	**E.5. Open Source Availability**
10	the capability of the software product to be modified which may include corrections, improvements or adaptations of the software to changes in the environment and in the requirements and functional specifications (the effort needed for modification)	Can faults be easily diagnosed?	Can the software be easily modified?	Can the software continue functioning if changes are made?	Can the software be tested easily?	Is source code of the cloud based application available to the general public for use and/or modification from its original design free of charge?
11	**F.Portability**	**F.1. Adaptability**	**F.2. Installability**	**F.3. Conformance**	**F.4. Replace ability**	
12	the capability of the software product to be 'transferred from one environment to another. The environment may include organizational, hardware or software	Can the software be moved to other environments?	Can the software be installed easily?	Does the software comply with portability standards?	'Can the software easily replace other software?' Is there any migration support mechanism? Is there any system setting configuration? Is there any standard format support? How is the system' s data export capability?	
13	**H. Elasticity**	**H.1. Multi-client Access Adjustment**	**H.2. Resource allocation adjustment**			
14	"how much a Cloud service can be scaled during peak times. This is defined by two attributes: mean time taken to expand or contract the service capacity, and maximum capacity of service."	"based on virtualization and load balancing technologies, IT infrastructure and application are shared across clients"	"upscale or downscale user IT requirements as and when required"			
15	**I. Security & Privacy**	**I.1. Authorization**	**I.2. Audit**	**I.3. Protection**	**I.4. Multi-Location Issues**	
16	confidentiality (unauthorized revelation of data), integrity (unauthorized operation and destroying data), tracebility,protection and multi-location issues	"policies and processes in use by the cloud provider to ensure that only the personnel granted appropriate privileges can make us of or modify data/work products" "integrity (unauthorized operation and destroying data), confidentiality (unauthorized revelation of data) , controlling unauthorized modifications on the system" Are criticial operations of each user controlled and secured? Critical operations: – installation, changes, and deletion of virtualized devices such as servers, networks and storage; – termination procedures for cloud service usage; – backup and restoration and etc.	the capability to monitor specified aspects of the operation of the cloud services that the cloud service customer uses. For example, to monitor and detect if the cloud service is being used as a platform to attack others, or if sensitive data is being leaked from the cloud service. Does the cloud service provider meets customer requirements of event logging, monitoring requirements? Is there any mechanism to monitor critical operations which are stated in Section I.1. and SLA terms.	Is there any data protection mechanism such as encyripted storage to protect Personally Identifiable Information (PII), or Is there any cryptographic controls for the use of cloud services? Does the cloud provider meets the requirements of network, physical and environmental and overall system security requirements in terms of hardware and software? (e.g., VLAN,Firewall, packet filters, SSL etc.)	"Client constraints on cloud service location based on the geographic or political risk " -Storage of private data (how well private data is protected from a confidentiality aspect) - multi-location of private data (where the data is stored) -multi-location of service provider (where the service providers's server is located and operated) -data transfer accross the border (where the data is transferred)	
17	**J. Policy & Regulations**	**J.1. Compliance**	**J.2. Legal requirements/Obligations**			
18	Does the cloud based information system comply with standards, domain-specific requirement and legal regulations ?	Does the software comply with standards and domain-specific requirements? For example, for health-care industry, Health Insurance Portability and Accountability Act (HIPAA) push companies to comply with HIPAA even if they're not operating in that market, but store health-related information about individual employees.	Does the software comply wiht legal regulations and obligations? Is there any country specific laws? For example, if the tenant or cloud customer operates in the United States, Canada or the European Union, they're subject to numerous regulatory requirements. These include Control Objectives for Information and related Technology and Safe Harbor. These laws might relate to where the data is stored or transferred, as well as how well this data is protected from a confidentiality aspect.			
19	**K. Customer Service Quality**	**K.1. Technical Support**	**K.2. Customer Support**			
20	Customer service is the provision of service to customers before, during and after a purchase. 24x7 technical/customer support availability, personnel training hours , availability of a dedicated support team are identified as attributes of the customer service quality.	technical support services attempt to help the user solve specific problems with the product of Cloud-EIS rather than providing training or other support services. Is there any dedicated support team for technical support? Can the customer service fix technical problems in a specified period of time? What is the working hours of the technical support team in customer service department?	customer support is a range of customer services to assist customers in making cost effective and correct use of a product. It includes assistance in planning, installation, training, troubleshooting, maintenance, upgrading, and disposal of a product. Is there any dedicated support team for customer support? What is the working hours of the customer support team in customer service department?			
21						
22						
23						
24						

Functionality / Reliability / Usability / Efficiency / Maintainability / Portability / Elasticity / Security & Privacy / Policy & Regulations / Customer Service / Appendix A

Figure 28: The Appendix of the AHP Survey (Part 2)

APPENDIX C

Ethics Committee Approval Letter

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İnsan Araştırmaları Etik Kurulu Başkanı

İlgi: Etik Onayı

Sayın Yrd.Doç.Dr. P.Erhan EREN

Danışmanlığını yaptığınız Umut ŞENER'in "Bulut Tabanlı Kurumsal Bilgi Sistemleri Kalite Faktörlerinin Önem Sıralaması" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2016-FEN-046** protokol numarası ile **30.06.2016-09.09.2016** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ayhan SOL

İnsan Araştırmaları Etik Kurulu Üyesi

Figure 29: Ethics Committee Approval Letter