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Assessment Of Non-Functional Properties For E-services

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ABSTRACT

Non-functional properties (NFPs) for an e-service consist of qualities and features that are desirable by the service users. Unlike functional properties, which are tangible functionalities provided by the e-service, NFPs are often hidden or transparent to service users. These properties are formally or semi-formally expressed to service developers by the service user and are then transformed into non-functional requirements (NFRs) by the developers. Currently, both NFPs and NFRs are often overlooked by the service developer or added to the service later in an ad hoc manner. In this paper, we discuss the identification of NFPs by service users as part of the requirements for the engineering phase of the e-services software development life cycle. To help capture NFPs, we provide a comprehensive taxonomy for identifying their properties based on the categories of trust, user experience, quality of service, and conformance. The taxonomy is then used to develop a tool for assessing the NFPs in online banking e-services. The tool is applied to a case study, and the results are reported and empirically analyzed.

Keywords: E-services, Elicitation, Non-functional properties, Requirements, Taxonomy.

INTRODUCTION

The introduction of the web in the mid-1990s transformed information exchange methodology. Electronic service (e-service) is a new term that was introduced in recent years to describe services that are provided over the internet via mobile- or web-based systems to various types of users. E-service providers offer users low-cost, time-saving services compared with traditional service providers. The advances in information and communication technologies facilitate adapting e-services in different areas such as e-learning, e-communities, e-training, e-games, e-health, e-entertainment, e-government, e-procurement, e-voting, e-banking, e-finance, e-bartering, e-trading, e-marketing, e-publishing, and e-journalism. Some of the main advantages of e-services include greater availability, reduced operations and overhead costs, customization, and streamlined and optimized business processes, all leading to an increase in the quality of services.

From a software engineering point of view, we may consider e-services to be products. The effective identification of requirements ensures a reliable e-service. Requirements are broadly categorized as functional or non-functional. Functional requirements (FRs) are related to visible, user-interface-driven functionalities that allow the user to interact with the system. By contrast, NFRs are desirable qualities that have restrictions that must be imposed on the system as a whole (generic) or specific to particular functionalities. One of the main reasons for low-quality e-services is that the NFPs desired by e-service users are often not satisfied in the delivered service. NFPs are

related to the e-service's desirable qualities as perceived by its users. These NFPs are identified by the e-service developer during the requirements specifications phase and are documented as NFRs (Chung et al., 2000; Chung and do Prado Leite, 2009) associated with the e-service functionalities or functional requirements. Figure 1 illustrates the transformation between NFPs and NFRs. These properties cover both technical and non-technical aspects of the e-service. To develop the e-service, we use the NFRs that originate from the NFPs during the initial phases of the software development process. Often, the user expresses desirable system properties using informal and unquantifiable terms, for example, by requesting a 'fast' system. The requirement engineer transforms this request into a more precise and quantifiable property, such that a user may get his request in response time less than 10 ms.

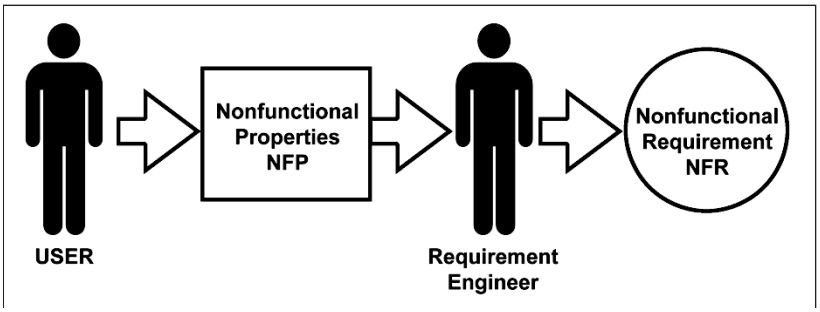

Figure 1. Transformation from NFPs to NFRs.

A common approach to describe requirements is to develop use case models that capture the functional requirements (Booch et al., 1999). Use case models consist of a set of use cases, each of which describes a certain functional requirement. The requirement engineer must also capture and explicitly specify the desirable NFPs that are associated with each use case in the model. NFPs include properties such as security, cultural, political, and standards conformity, reliability, and performance. Some NFPs are quantifiable and are transformed into possibly automatically verifiable requirements (Saleh, 2009; Robertson and Robertson, 1999). In addition to use-case-based NFPs, other NFPs are generic and affect all use cases in the software implementation of the e-service. Quantifiable NFPs can impose some decisions on the possible higher level design or architectural choices and on the detailed design phase of the e-service development. On the other hand, generic NFPs, such as standards conformity properties, are mostly non-quantifiable and can only be verified using a non-automated and informal review procedure. The comprehensive and correct identification of the desirable NFPs is critical for developing usable and feasible e-services. The requirement engineer must be aware of any contradictions in the desirable properties. For example, a security-related non-functional property may negatively affect the e-service's performance as it may require the exchange of extra messages or extra processing. Meanwhile, a performance-related NFP will primarily positively affect the e-service user because reduced response time delays and the efficient use of memory will be noticed by the user. However, a performance-related NFP will also affect the developer because incorporating this property will require some performance considerations that must be addressed during the design and coding phases of the e-service development process. Some other e-service quality

attributes directly affect the developer but can also have a direct impact on the users. Currently, NFPs are often overlooked by the e-service developer or they are informally considered later for incorporation into the service. Proper identification of desirable NFPs is missing in the literature. Moreover, previous attempts considered NFPs that were elicited from the developer's point of view when they should also have been obtained from users. In this paper, we address the concerns that hinder the rapid growth in the adaptation of e-services, such as privacy and business integrity concerns, concerns that affect the trustworthiness of e-services in general. The ultimate goal of this paper is to improve the design of e-services. To achieve this goal, the paper addresses the following two key research questions:

RQ1: What are the categories of NFPs of e-services?

RQ2: How to quantitatively assess the NFPs of an e-service?

We are mostly concerned with quality criteria or properties that are looked at from the user's perspectives. These are referred to as NFPs as opposed to the NFRs imposed on the development process. To address the above research questions, we clustered related NFPs to assess them in a comprehensive and more formal way, and we have provided an assessment tool to serve that purpose. The tool can be considered in two ways: prior to implementing the e-service and/or afterwards. To minimize unwanted and unexpected implementation costs, developers should find this tool useful for eliciting NFRs of the e-service. Conversely, e-service owners can use the tool to evaluate the developed e-service and improve its quality and performance based on the assessment results. Moreover, an external quality assurance organization can use the tool to evaluate the NFPs of a developed e-service and pinpoint its weaknesses and deficiencies.

The types of NFPs that must be carefully and comprehensibly considered when planning and developing the e-service are introduced in the following sections.

The main contributions of this paper are as follows:

1. We identify the NFPs of e-services based on four categories: trust, user experience, quality of service, and conformance.
2. We propose a tool that assists in the quantitative assessment of the NFPs of an e- service.
3. We choose e-banking as a case study to apply the tool and assess the NFPs of several e-banking services.
4. We use the results to empirically demonstrate the applicability and comprehensibility of the proposed tool.

The remainder of the paper is organized as follows. Section 2 reviews background and related work. Section 3 addresses the NFPs related to trust, the user's experience, the quality of service, and conformance. In Section 4, we present the NFPs of the e-service assessment tool. In Section 5, we report and discuss an empirical study's results. Finally, Section 6 concludes the paper and provides directions for future work.

BACKGROUND AND RELATED WORK

Background

NFRs for e-services have been thoroughly studied in the literature. We highlight some leading research in the area. IEEE (1998) listed thirteen NFRs as recommended for inclusion in the software requirements document. These NFRs were, however, not classified. They include performance, interface, operational, resource, verification, acceptance, documentation, security, portability, quality, reliability, maintainability, and safety requirements. Some researchers addressed NFRs from a pure software engineering perspective such as the work by Chung and do Prado Leite (2009), and Cysneiros and Leite (2004).

Jacobson et al. (1999) classified NFRs based on the FURPS+ model (Grady, R. B. & Caswell, D. L. (1987)). The list of NFRs included usability, reliability, performance, and supportability, in addition to general NFRs like implementation, interface, operations, packaging, and legal requirements. Some of these NFRs were further labeled; for example, performance requirements include speed efficiency, resource usage, throughput, and response time requirements.

In addition, quality and adoption issues for online services were addressed in Gounaris et al. (2010), Saleh (2010), Huang and Benyoucef (2013, 2014), and Yang (2005). Country-specific research on issues of quality and adoption covered many countries in different continents. The criteria and approaches used lacked uniformity due to the absence of a unified definition of quality factors and criteria for assessment in general.

Related work

We provide an overview of the work related to the aspects of our research, namely, the issues related to the criteria for the assessment of online services, and the classification of NFPs of e-services. We also include related work of e-banking services to support our case study and finally analyze the related work to show the motivation of our proposed development.

Boehm et al. (1976) introduced a classification of NFRs based on a software quality tree. The tree included as intermediate nodes qualities such as portability, reliability, efficiency, testability, understandability, and modifiability.

McCall et al. (1977) listed NFRs as software quality factors. NFRs were classified under three perspectives according to the product life cycle, namely, product operation, revision, and transition. During product operations, NFRs such as usability, integrity, efficiency, correctness, and reliability were identified (Jaramillo, 2011).

ISO/IEC IS 9126 (2001) classified NFRs in a quality model for external and internal quality. The NFRs included reliability, usability, efficiency, maintainability, and portability requirements, each of which was further classified. For example, efficiency included time behavior and resource utilization.

A survey of quality models in software engineering was carried out by Al-Qutaish (2010). Sommerville (2011) classified NFRs under three types, namely, product, organizational, and external requirements. Each type was further classified and included different subtypes of NFRs.

For example, product requirements include usability, efficiency, dependability, and security requirements. Efficiency requirements include performance requirements and space requirements. External requirements include regulatory, ethical, and legislative requirements.

E-banking related work

Many researchers have addressed issues related to the adoption of various domains of e-services, prominently, among which are e-banking services. Published work in the domain of e-banking or online banking addressed either country-specific issues or generic issues related to quality issues and adoption criteria. The later issues were studied by Herington and Weaven (2007), Ameller et al. (2013, 2015), Ojasala (2010), Raman et al. (2008), Rababah and Masoud (2010), and Roy and Balaji (2015).

As mentioned before, some works include finding requirements of e-services based on the country of the service. The following show some country-based research on e-backing. Factors that affect the embracing of e-banking in India were investigated by Ali and Bharadwaj (2010). According to their findings, the prominent factor was ease of use, followed by customer-bank trust, cost of computers, internet accessibility, and security concerns. Varaprasad et al. (2013) identified key determinants for embracing e-banking in India and included conspicuousness as a new determinant. In another study by Nyangosi and Arora (2011), the most significant factors that hindered the adoption of e-banking service in both India and Kenya were privacy issues, the high cost of adoption, the lack of appropriate infrastructure, and e-crime concerns.

Obstacles that affected the embracing of e-banking services in Portugal were investigated by Ferreira and Barata (2011). Factors that influence the embracing of e-banking in Malaysia were presented by Tan et al. (2010). Their study indicated that accessibility, convenience, professed usefulness, efficiency, and security figured prominently among these factors. The authors showed also that customers prefer e-banking (via PC) over mobile e-banking (via smart phones).

The benefits and risks associated with the use of e-banking in Pakistan were presented by Shabbir et al. (2011), and the reported results indicate that customers fear privacy issues. Chandio et al. (2013) developed a technology acceptance model and used it to assess the acceptance of online banking information systems in Pakistan.

The use of online banking by young users was investigated by Kalaiarasi and Srividya (2013). Their study reported that young users adopt online banking based on its user-friendliness and suitability and that security risk does not appear to be a concern for them. Al-Weshah (2013) concluded that e-banking is considered an opportunity for the continuous improvement of already provided banking services. A web banking system that addressed security and effectiveness concerns was developed and evaluated by Mitropoulos et al. (2013). An evaluation of internet banking in New Zealand was conducted by Chung and Paynter (2002) and addressed both functional and NFPs. NFPs included the ease of use, performance, and security. It was found that although security concerns are very important, users felt secure using internet banking. A similar evaluation of internet banking and online brokerage in Tunisia was conducted by Achour et al. (2005) and was used to rank financial institutions on both functionalities and NFPs such as ease of use and security.

Analysis of related work

Previous work on the assessment of e-service, and specifically on e-banking services, lacks clear criteria for the assessment of such services. The terminology used is not common and inconsistent. Various general assessment criteria were proposed. We believe that well-defined and common criteria dealing with desirable properties for e-services need to be developed to uniformly assess the existing e-services, and possibly guiding and positively influencing the design of new e-services. We are mostly concerned with quality criteria or properties that are looked at from the user's perspectives. These are referred to as NFPs as opposed to the NFRs imposed on the development process. In the context of web services, Becha and Amyot (2012) identified NFPs in service-oriented architectures for web services and assessed them as a result of a survey questionnaire completed by potential web service users. As a result of the survey, seventeen consumer-oriented NFPs were identified, namely, price, response time, reputation, certification, availability, accuracy, reliability, collapse modes, usability, standards conformity, transactional service, security, jurisdiction, service versioning, resources, scalability, and service location.

In our work, we assess the existing e-services from the user's perspective by surveying the user's experience with an e-banking service as a case study of our classification NFP. We propose an assessment tool designed in accordance with our proposed classification of NFPs.

CLASSIFICATION OF NFPs

In this paper, we are interested in a classification that emphasizes the user's perception of the qualities an online service should possess. We refer to them as NFPs as opposed to the developer's perception ones known as NFRs. Several published papers, as stated in the previous section, listed different lists of properties without any classification, and none of the lists were comprehensive enough.

We introduce a plausible categorization of e-services' properties consisting of four categories, namely, trust, user experience, service quality, and conformance. Each category covers a cohesive and comprehensive set of concerns or desirable properties of e-services. Our categorization is based on the clustering of related properties dealing with the most important user concerns.

Typical users are mostly concerned with their experiences while using the service, their trust in the provided service, the quality of the service offered, and its conformance to relevant standards. Each category is then divided into sub-categories joining together strongly related properties within the category. Depending on the type of e-service under consideration, the property is determined whether to be applied to the whole service or only to specific function(s) within the service (Saleh 2009). Properties that are mostly service-wide are examined first. Standard conformity is an example of a service-wide property. The less generic properties are then considered. Examples of such services are use-case-dependent services, such as security. Following this approach, we aim to enforce the desirable properties from the generic or system-wide NFPs to the more specific ones. NFPs can be documented separately in the e-service requirement document if they are applicable to the whole service system. By contrast, NFPs that are specific to a particular service function can be added to the use case description.

Trust-related NFPs

Trust properties are related to the user's perception of the e-service as it pertains to concerns that may affect the level of user trust. Privacy preservation, safety, and security properties affect the user's trust.

Privacy preservation properties are related to the features and facilities provided by the service to protect the privacy of its users. A suitable privacy policy developed by the service provider can address how users' private information is appropriately managed and the user's degree of control over his own private information (e.g., cookies). Hence, the user can opt for faster access and keep the cookies or protect their privacy and delete them.

Safety properties are related to the fact that, after using the e-service, the user should feel safe, whether financially or physically. The service should protect the user from abuse and identity theft by malicious attackers that could eventually lead to financial hardship or physical harm.

Security properties are critical and need to be recognized during the initial phases of the service development process. A security property is attached to either a use case or the whole service under development. Typically, a security property addresses one or more of four essential principles: (1) confidentiality, (2) integrity, (3) availability, and (4) accountability (Saleh, 2012). These principles are addressed by imposing and adhering to multiple security-related properties. These desirable properties must be transformed to service security requirements by the requirements engineer (Firesmith, 2003).

Properties associated with access control are used to address confidentiality issues at the physical level. These properties are related to specific use cases or are applicable to the whole service. The service owner may mandate that certain service functions only be available to identified, authenticated and authorized users, while certain other service functions can be publicly and unanimously accessible.

Integrity concerns are approached using integrity, immunity, and privacy properties. An integrity property should be applicable to all the offered service functions. Availability concerns are mainly addressed using survivability and physical protection properties. A survivability property is typically a property of the whole service system. However, it can also be applicable to specific service functions depending on their criticality to the overall service offering. Availability properties are perceived by users as the existence and accessibility of the e-services anytime and anywhere. This property is maintained by the existence of an active business continuity plan and proper capacity planning.

Accountability concerns are addressed using non-repudiation and standards conformity properties. Accountability properties are typically applicable to critical service functions because it may be cumbersome and resource-consuming to trace all of the activities performed on the service system. However, standards conformity properties are typically applicable to the service system as a whole. Although security properties are normally considered to be NFPs, some of them must be addressed by first recognizing the functional properties that are relevant to security. Providing a logon use case as a functional requirement can satisfy multiple security properties such as authentication. These types of use cases that meet both functional and NFRs are called security use cases (Saleh, 2012).

User-experience-related NFPs

User-experience properties are highly crucial for the economic bottom line and feasibility of the e-service. To identify these properties, the proper stakeholders must thoroughly examine the property types specified below.

Interoperability properties allow users to interact and use the service functions from a variety of hardware platforms, communications access points, and browsers. Typically, an interoperability property imposes certain limits on the systems categories with which the service can interface. An e-service might have to interface and communicate with other e-services, software systems, and hardware devices. These types of interactions should be transparent and seamless to users.

Supportability properties specify the features or highlights of the available support to the service after it has been deployed and used by service users. The supportability properties typically include the required user documentation and training.

Usability properties specify the constraints and success criteria imposed by the service owner or selected users as representatives of the service user community. The objective of these constraints and criteria is to ensure that the e-service is accessible by the different users who interact with its service functions. The usability properties are normally recognized by first identifying the targeted service users and their experiences, and they are typically quantitative to enable checking them in the final service product. User friendliness is one aspect of usability, which makes the service easy to use. Ease of navigability and the availability of friendly help, warning, and error messages are examples of user-friendliness. Typically, a highly usable service is also a user-friendly service. Familiar or standard 'Look and Feel' can also make the service more usable. The look and feel could be either a unique and innovative approach to the user interface or an adaptation of an existing standard or of a proven look and feel that was used in other software systems.

Quality of service-related NFPs

Quality-related NFPs are concerned with conditions that are desirable by the service users during the service delivery and must be conserved after any maintenance is performed on the service. These properties must be carefully identified by iteratively communicating with the relevant stakeholders to obtain realistic and achievable properties. The properties would typically be included in a service-level agreement to be honored by the service operator.

Performance properties describe technical features and constraints related to service delays, throughput, and effectiveness and to the memory requirements needed to run the service. Response time delays can be either different for different service functions or fixed for the whole service system. Response-time-related performance properties can also be stated as throughput properties, setting limits on the acceptable rate of transaction completions. Scalability, as a non-functional property, is reflected to users as a performance property. For example, low scalability may lead to longer response times and hence lower performance.

Reliability properties describe certain values relevant to the reliability of the service system in consideration. The mean time between failures (MTBF) or the maximum time allowed for failures over a specified period are usually reliability values. Service reliability can also be classified under trust because the more reliable the service, the higher the user's trust in the service. Robustness and resilience as NFPs manifest themselves to users as reliability properties. For example, weak service robustness may lead to a less reliable service. It is also clear that the more available the service is, the more reliable it is.

Conformance-related NFPs

Conformance-related NFPs are mainly descriptive and non-quantifiable properties that may directly or indirectly affect the success of the service system. The appropriate stakeholders should thoroughly study every property type indicated below.

Cultural properties clearly specify the cultural and political contexts in which the service will operate. These properties have to be considered early during the planning phases of the e-service. Before the e-service is deployed, the engineer must realize the cultural sensitivities of the countries in which the e-service will be used. These could include language issues, use of symbols, and politically offensive contents. Failure to properly discover and capture these cultural properties can affect the service's acceptance and popularity. Should these properties be viewed differently in different countries or societies, multiple versions of the e-service may have to be developed and deployed.

Legal and **regulatory** properties describe both the legal and regulatory contexts in which the service system operates. The e-service should observe and adhere to both the local and international rules and regulations of the countries where it will be deployed. The development team, for instance, should avoid including persons who do not meet certain security clearance levels. Moreover, the e-service itself should be in line with copyright laws and regulations. Failure to observe and include these properties makes the e-service susceptible to criminal inquiries and claims, affecting the status of the development and service owner organization.

Standards conformity properties describe the standards or parts of them that must be adhered to when developing the e-service. Standards have various levels and categories. Internal standards can also be developed by the e-service owner and development organizations. The client and developer should be aware of any specific country standards (e.g., military standards), and any professional standards can also be referred to among these properties. Standards developed by international organizations such as ISO or ITU and other relevant industry-related international standards can also be listed as standards conformity properties. Both the e-service engineer and client must adhere to the standards related to the e-service's application domain. Failure to adhere to the stated standards often leads to the delayed release of the e-service. Therefore, the developer should be familiar with the service application domain, and these properties must be elicited carefully and explicitly.

NFPs OF THE E-SERVICE ASSESSMENT TOOL

To address our second research question, we have developed an assessment tool that allows e-service users to quantitatively evaluate the NFPs for an e-service and thus helps service providers identify the corresponding weaknesses and strengths. There are three types of users: experienced, average, and users with no experience. We have assumed in this paper that users have on average a natural experience. The assessment tool consists of a set of 50 questions that cover the four categories and subcategories that were identified earlier and tailored for e-banking services. The initial set of questions was larger, and a pilot study was conducted in which a group of 10 people from different technical backgrounds were asked to complete the assessment tool. Based on the pilot study, we decided to reduce and improve the clarity of the questions, reaching a final set of 50 questions. Based on these questions, a survey was designed and published online on SurveyMonkey. The question order was arbitrary in the survey, although, for better readability, they are ordered by categories and subcategories in Table 1. The survey questions are provided in both Arabic and English. For each question, the e-service user selects one of the following options: fully satisfied, often satisfied, average, rarely satisfied, and never satisfied. The answers are mapped to the values 100%, 75%, 50%, 25%, and 0%, respectively. The questions within each subcategory are equally weighted. Therefore, to assess an e-service for its compliance with a certain NFP subcategory, the average of the user responses for the questions in that subcategory is obtained. To evaluate an e-service for its satisfaction regarding a certain NFP category, the average of the averages obtained for the subcategories is calculated. For example, to assess an e-service for its satisfaction of the trust NFP, the users' responses to each of the corresponding twenty-two questions are collected. The average values for the responses to the first two questions are used to evaluate the safety (subcategory) NFP, the average values for the answers to the next fourteen questions are considered to assess the security (subcategory) NFP, and the average values for the replies to the following six questions are used to evaluate the privacy preservation (subcategory) NFP. The average of these three average values is calculated to indicate the user assessment of the trust (category) NFP. In our analysis, we considered the 75% level (often satisfied) to be acceptable.

Table 1. Users' survey questions and responses.

Category	Subcategory	Question No. within each subcategory	Average Total (%)	Average value for subcategory (%)
Trust (78.15%)	safety (I.1)	Do you consider the e-service safe and you feel comfortable using it?	93.64	82.31
		Do you get reminders and hints on how to make your e-service use safer (e.g., periodic reminders to change your password)?	70.97	
	security (I.2) (confidentiality, integrity, availability, accountability)	Does the e-service require you to use strong passwords?	75.42	77.28
		Did you experience any tampered (i.e., illegal or unauthorized) access to your account?	91.95	
		Did you experience any problem with your account as a result of a transaction?	87.71	
		Are you able to trace back any transaction that you have made or ask for details about it?	86.02	
		I Do you feel that the authentication procedure used is sufficient to give you the feeling of security? (for example, it requires you to change the password regularly)	85.17	
		Do you feel that the e-service provider is constantly trying to improve the security aspects (such as access control)?	87.5	
		Were you exposed to a phishing incident that led to identity theft? (Phishing is the attempt to deceive Internet users into disclosing personal information through the use of an official-looking e-service provider)	88.56	
		Do you feel that the e-service provider assumes responsibility and takes corrective actions for any wrongdoing on its part or the part of a third party?	71.61	

		Do you consider the e-service available anytime you need it?	88.14	
		Were you able to access the e-service from anywhere you needed to access it?	90.25	
		Were you informed ahead of time of e-service interruptions or unavailability?	42.58	
		Did you experience any e-service breakdown while you were using it?	71.82	
		Are you aware of any published information on service failure frequency by the e-service provider?	37.92	
		Are you aware of any published information on service failure frequency by the e-service provider?	38.56	
	privacy preservation (I.3)	Did you read and agree to the privacy policy when joining the e-service?	60.17	
		Do you think that the e-service provider is adhering to the privacy policy?	78.6	
		Are you able to modify your private information any time you desire?	77.12	
		Is it easy or possible to cancel your participation in the e-service any time you desire?	69.7	74.86
		Do you feel that the e-service provider is passing your private information to third parties without your consent?	75.85	
		Do you feel that the e-service provider values the importance of protecting your privacy?	87.71	
User Experience (80.61%)	Interoperability (II.1)	Are you able to access the e-service using different types of terminal devices, e.g., laptops, smart phones, etc.?	93.22	
		Are you able to access the e-service using different web browsers (e.g., Internet Explorer, Firefox, etc.)?	84.11	85.88
		Does the e-service interoperate well with peripheral devices such as printers?	80.3	
	usability and user friendliness (II.2)	Do you consider the e-service web pages easy to navigate?	89.41	
		Is the e-service interface rich in components that make your use of the service efficient and satisfying?	88.56	
		Do you think that the interface can be customized to make it more suitable to your needs and uses?	68.43	
		Are the e-service features easy to remember when using them or do you have to seek help every time you need to use a feature?	84.75	
		Is it easy to install the e-service application on your smart phone or tablet?	91.31	81.17
		Is it easy to remove the e-service application from your smart phone or tablet after you have installed it?	86.23	
		Does the service allow you to undo or confirm any action?	73.09	
		Are the error messages, help messages and warning messages friendly, courteous and useful?	83.05	
		Is the e-service interface similar to familiar interfaces that you consider popular and desirable?	65.68	
	supportability (II.3)	Is the e-service provider committed to responding within a reasonable time when solving a service reported problem?	71.61	
		Did you receive the proper technical support when you needed help using the e-service?	79.24	
		Is there online help (such as an FAQ) available when needed?	73.94	74.79
		Do you know how to report service problems if you encounter them as you use the e-service?	76.48	
		Did receive get the proper feedback from the provider when you reported a problem?	72.67	
Quality Service (73.82%)	performance (III.1)	Do you experience delays in loading the e-service?	68.22	
		Do you find that the provider's strong authentication measures, although they make the service more secure, irritate you and make the e-service unfriendly?	46.4	
		Do you experience noticeable delays when you access the e-service?	72.25	61.19
		Regardless of your location when you access the service, do you have the feeling that the e-service facilities are nearby (i.e., location transparency)?	80.08	
		Were you aware of any performance properties and requirements regarding memory and speed when you subscribed to and installed the e-service?	38.98	
	reliability (III.2)	Do you consider the e-service reliable in the sense that it has always performed the requested service, nothing less and nothing more?	86.44	86.44
Conformance (74.23%)	Cultural (IV.1)	Is the e-service available in your mother language?	91.74	84.75
		Do you have the choice to change the language of the interface?	89.41	
		Are the messages provided by the e-service culturally sensitive?	73.09	
	legal and regulatory (IV.2)	Do you think that the provided e-service complies with the service level agreement you agreed to when you subscribed to the service?	80.51	80.51
	standards conformity (IV.3)	Are you aware of whether the provided e-service conforms to country, regional or international standards?	57.42	57.42

CASE STUDY: E-BANKING ONLINE SERVICES

To demonstrate the applicability of the proposed assessment tool, we made the corresponding survey available online on SurveyMonkey and collected the responses of 118 e-banking service users around the world. In this case study, we attempted to assess the e-service provided by banks; both international and local banks that provide e-banking services were considered. Respondents who used e-banking services from different banks were allowed to complete the survey twice. Figure 2 depicts the location of e-banking service providers for the respondents.

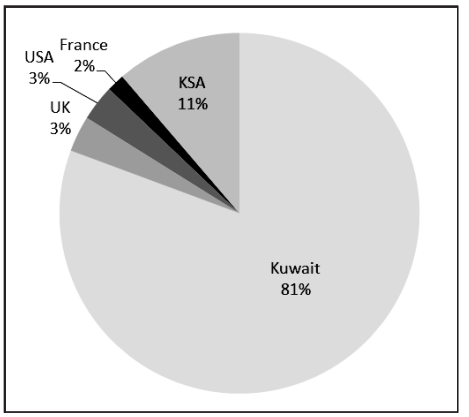

Figure 2. Locations of e-service providers.

We noticed that 50% of the respondents were females. The age group of the participants varies as shown in Figure 3.

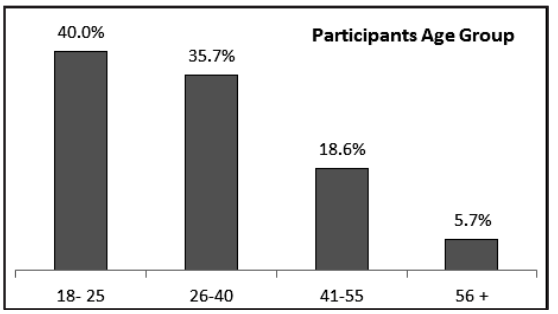

Figure 3. Participants age group.

The collected results are used to perform two empirical analyses. The first analysis studies the correlations among the survey questions. The goal of this analysis is to empirically explore the degrees of overlap between the survey questions. A low degree of overlap indicates that the survey is properly designed and that the questions consider different NFR aspects and that, therefore, all questions must be considered when assessing the NFP of an e-banking service. The second analysis investigates the range of aspects considered by the survey questions and the contribution of each question to each NFP aspect. The goal of this analysis is to empirically show that the proposed questions cover a wide range of NFP aspects and that a question contributes mainly to a certain aspect and partially to other aspects, which empirically indicates that the considered NFPs are not orthogonal.

Survey results

Figure 4 shows the percentage of satisfaction for each of the four NFP categories based on our classification. The e-banking service was considered trustworthy based on the user rating of 78.15%, (only 3% above the accepted level). Similarly, users were happy with their e-banking experiences; their average ratings were 80.58%. By contrast, as Figure 4 depicts, the average ratings for both service quality and conformance were below the accepted level (75%). The conformance response was 1% below the accepted value, and the service quality was below the accepted value at 73.8%. The low score for service quality could be attributed to the performance subcategory, as shown in Figure 5. The low score indicates users' dissatisfaction with the quality of the service. The assessments of each subcategory within each category related to the user's perception of the e-service are displayed in Figure 5.

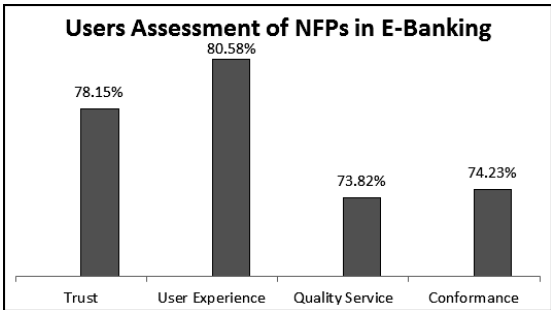

Figure 4. Overall assessment of the four categories of non-functional properties.

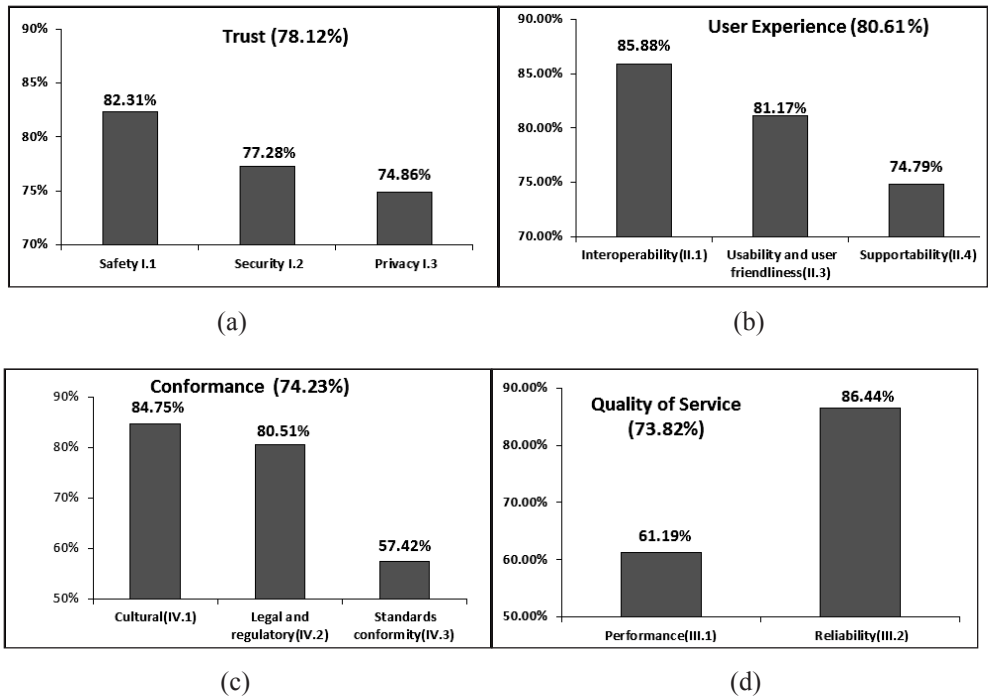

Figure 5. User responses in the subcategories within each NFP category.

Because the number of questions within each category is not equal, the users' responses for each question were further investigated. Table 1 shows the percentage of user responses for all questions within each property to pinpoint each question's weakness and its impact on the overall result. The overall average for each category could have hidden weaknesses at the subcategory level; for example, the case for user experience 80.61% (above 75%) hid a problem in the supportability subcategory, which was assessed at 74.79%.

Moreover, the average at the subcategory level could have also hidden weaknesses at the question level. For example, the acceptable average for the usability and friendliness (II.2) subcategory is 81.17%, but for question II.2.9, the satisfaction level was 65.68%, which is far below the acceptable level. Consequently, to be able to clearly pinpoint the markers that contribute to low satisfaction levels and to identify them to the service provider, it is more beneficial to consider the evaluation at the lowest level (i.e., the question level). This will allow the service provider to develop a more focused plan to achieve higher user satisfaction that can be measured again at a later stage to assess the effectiveness of the implemented enhancements.

Correlation study

We applied the correlation study to the collected results to explore the correlations between the answers to different questions. We evaluated the distribution normalities of the answers to all fifty questions using the Shapiro-Wilk normality test (Rosenkrantz, 2008), and none were found to follow the normal distribution. Therefore, we applied the Spearman non-parametric correlation test to explore the correlations between each pair of questions. Most of the correlations were found to be statistically significant (p-value < 0.05), which indicates that the results allow for drawing corresponding conclusions.

The largest correlations were found between the answers to the first two questions in the cultural subcategory (0.63), between the answers to the last two questions in the supportability subcategory (0.62), and between the answers to questions II.2.5 and II.2.6 in the usability and user friendliness subcategory (0.55). The absolute values for the remaining correlations are below 0.5, which indicates that the correlations are weak or even unreliable. These results empirically show that the overlaps between each pair of questions on the user›s survey are weak or negligible. This observation indicates that the questions are orthogonal and different than each other, and it gives confidence that the survey is well designed. Therefore, to assess the considered NFPs, the questions included in the survey must be considered together.

Principal component analysis

Principal component analysis (PCA) (Dunteman, 1989) is a technique used here to identify and understand the underlying orthogonal dimensions that explain the relationships between the survey questions. To obtain the principal components (PCs), we used Varimax rotation (Jolliffe, 1986; Snedecor and Cochran, 1989), in which eigenvectors and eigenvalues (loadings) are calculated and used to form the PC loading matrix as follows.

1. We constructed the correlation matrix (CM) (as indicated in Section 5.2).
2. We obtained the eigenvalues and eigenvectors for matrix CM.
3. We formed a primary PC loading matrix (PLM). Each eigenvector forms a column in the PLM and corresponds to a PC in the PC loading matrix.
4. We sorted the eigenvalues in descending order and reordered the corresponding eigenvectors in the PLM accordingly.
5. We calculated the percentage of each PC as the percentage of the eigenvalue of the PC to the summation of the eigenvalues of all PCs.
6. We constructed the PC loading matrix. Each entry in a column j in the PC loading matrix is calculated by multiplying the corresponding entry in column j, the PLM, by the square root of the eigenvalue associated to column j.

In our context, each PC in the matrix represents a NFP aspect that is considered in one or more of the survey questions. The value reported in row i and column j in the loading matrix represents the contribution of question i to NFP aspect j. To obtain a more informative PC loading matrix, we reported, in the matrix shown in Table 2, the percentage of contribution of each question to each PC, instead of showing the amount of contribution.

The application of the PCA to the survey answers showed that fifty different aspects were captured by the considered questions and that some of the aspects were covered strongly than others. Because of space limitations, Table 2 shows only the questions' contributions to the first 16 PCs in the loading matrix. The first row in the matrix shows the PC identifier. The second row shows the ratio of each PC to the total data set variance (i.e., in our context, the row includes the ratio of each NFP aspect assessed by the survey to the overall considered NFP concepts). The third row reports the cumulative percentages. For example, the PC loading matrix, given in Table 2, shows that 15.1% of the total variance of the considered aspects is covered by PC1 and that the percentage of contribution of question I.1.1 to aspect PC1 is 2.4%. The results show that only one PC captures 15.1% of the data set variance. The percentages of data set variance captured by each of the other PCs range from 0.1% to 7.9%. This observation indicates that the considered questions covered a wide range of NFP aspects and thus should be considered in total in the assessment process. In most cases, the PCA results also show that each question makes a relatively strong contribution to one NFP aspect and a week or negligible contribution to other aspects. This observation confirms that the questions are distinct and highlights the fact that the NFP aspects are related.

Typically, researchers provide interpretations for the PCs with relatively high loading percentages. Because most of the PCs have relatively low loading percentages, we will focus our explanation only on the first three PCs. Each of these PCs has more than 5% of the total variance. The interpretation of each PC relates the PC to the variables (i.e., survey questions) that have high contributions to that PC. We observed that the contribution percentages of the variables to each of the first three PCs are relatively low. To obtain more informative results that can be interpreted, we classified the questions based on their main NFR categories and calculated the contribution percentage of each category to each PC, as the summation of the contribution percentages of

the questions in the corresponding category. For example, we found that the summation of the percentages for questions in categories I, II, III, and IV is 40.3%, 44.2%, 8.5%, and 7.3%, respectively. As a result, we can conclude that the first PC is more related to the first two categories than to the other two categories and therefore, it captures aspects of trust and user experience NFRs. Questions in categories I, II, III, and IV have, respectively, 55.2%, 24.3%, 14.5%, and 6.2% of the total contribution to PC2, which indicates that PC2 is more related to NFR of category I than the NFRs of the other categories. Finally, questions in categories I, II, III, and IV have, respectively, 19.5%, 36.3%, 19.2%, and 24.8% of the total contribution to PC3, which indicates that PC3 is more related to NFR of category II than the NFRs of the other categories. Therefore, PC2 and PC3 capture aspects of trust and user experience NFRs, respectively.

Table 2. PCA loading matrix.

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**	**PC10**	**PC11**	**PC12**	**PC13**	**PC14**	**PC15**	**PC16**
Per.	15.1	7.9	5.5	4.9	4.5	3.8	3.5	3.3	3.1	2.9	2.9	2.6	2.5	2.4	2.1	2.1
C.Per	15.1	23.0	28.5	33.4	37.9	41.7	45.2	48.5	51.6	54.5	57.4	60.1	62.5	65.0	67.1	69.2
I.1.1	2.4	0.5	0.6	5.6	0.1	0.1	0.1	0.0	0.7	1.2	8.6	13.2	4.5	0.0	2.4	2.1
I.1.2	0.8	0.9	1.9	1.0	1.6	4.1	8.3	0.0	2.4	1.5	0.2	2.6	2.1	5.8	1.1	2.4
I.2.1	0.5	1.3	0.0	0.0	0.3	12.4	1.5	0.0	4.9	2.2	0.3	2.6	0.8	2.6	2.0	1.6
I.2.2	1.4	1.2	0.3	5.5	1.9	0.0	6.6	6.0	1.5	0.0	1.4	0.7	9.6	0.5	1.1	0.0
I.2.3	1.1	0.0	0.0	0.0	5.2	2.8	10.3	3.1	2.3	0.2	1.4	3.1	0.2	0.5	4.9	1.3
I.2.4	2.4	1.0	0.1	2.8	2.4	2.2	2.8	0.2	7.0	0.1	0.1	0.4	0.3	4.8	1.9	0.1
I.2.5	2.6	0.6	2.1	13.2	1.3	0.3	1.7	0.1	0.4	0.0	0.0	0.9	0.3	0.2	0.0	4.3
I.2.6	1.9	1.5	0.9	3.3	4.9	9.7	0.2	0.0	1.0	2.3	1.3	3.0	0.1	1.3	0.0	0.2
I.2.7	0.4	4.3	0.1	6.7	4.8	3.8	1.2	0.0	0.2	6.7	2.0	0.0	0.0	0.2	3.8	0.2
I.2.8	2.2	3.1	1.4	1.3	1.7	0.3	4.7	1.5	5.0	1.4	0.9	1.1	0.0	4.1	0.3	1.3
I.2.9	4.0	2.9	0.0	1.2	1.7	0.1	2.6	1.0	0.0	8.7	0.0	0.9	1.8	0.1	0.9	4.1
I.2.10	4.6	3.2	0.6	0.9	5.9	1.1	1.4	0.7	2.2	1.6	0.0	1.0	0.4	0.3	0.6	5.6
I.2.11	0.7	7.7	0.3	0.2	0.2	4.1	2.0	0.1	0.1	2.8	0.5	4.5	2.6	0.0	0.6	3.2
I.2.12	1.8	4.4	3.8	0.8	0.0	0.0	1.9	3.0	3.4	2.8	0.1	9.3	0.1	0.9	1.9	2.2
I.2.13	1.7	5.9	0.4	0.4	0.5	0.3	0.5	1.6	3.4	0.4	0.2	0.1	1.2	19.7	2.4	0.8
I.2.14	1.1	9.3	0.0	0.8	1.0	1.5	0.0	1.4	1.0	0.0	0.0	0.2	0.8	6.5	1.2	1.4
I.3.1	0.5	3.3	1.3	3.8	1.7	1.0	0.6	4.1	0.0	0.1	7.6	0.1	0.0	0.6	7.9	1.2
I.3.2	2.5	0.0	2.8	0.5	2.3	0.2	0.1	1.5	0.4	1.5	9.4	0.1	1.5	4.3	2.5	1.6
I.3.3	0.9	0.5	2.5	0.3	1.6	4.2	0.0	5.8	0.2	0.1	2.6	0.0	2.3	4.2	2.7	4.2
I.3.4	2.1	3.6	0.1	1.4	0.9	2.9	0.1	0.3	0.0	0.0	6.5	0.0	2.6	0.1	9.3	0.1
I.3.5	3.6	0.0	0.0	0.6	3.9	0.2	0.0	1.5	5.2	0.1	1.6	0.3	0.0	2.9	1.7	2.5
I.3.6	1.1	0.0	0.3	0.1	5.7	0.5	0.0	20.5	0.1	0.0	0.0	2.2	1.7	0.1	0.1	4.6
II.1.1	3.2	2.5	2.3	0.4	5.0	0.1	2.9	5.0	3.9	0.1	0.3	1.7	0.7	1.6	0.1	3.0
II.1.2	2.3	3.2	0.2	0.4	5.9	0.7	0.2	0.1	2.3	3.3	0.3	1.0	1.5	0.2	0.3	4.2
II.1.3	4.7	1.5	1.1	0.3	0.1	0.0	1.1	0.4	0.0	0.0	0.5	0.2	0.0	9.3	0.1	0.0
II.2.1	4.4	3.2	0.3	0.5	1.1	0.1	1.9	2.8	0.4	4.6	0.0	0.4	0.0	1.1	0.3	0.0

II.2.2	6.5	0.5	1.3	2.0	1.1	3.4	0.1	0.1	0.5	0.2	0.2	0.0	0.0	1.5	0.0	1.2
II.2.3	0.3	3.3	2.1	0.5	0.1	0.2	7.5	0.0	5.2	0.5	0.6	0.3	17.1	0.2	1.3	0.0
II.2.4	3.0	0.2	2.0	3.4	2.0	0.2	2.9	0.0	0.1	4.1	0.0	1.3	7.6	0.0	0.7	0.6
II.2.5	1.4	0.1	8.8	0.3	4.8	1.1	0.0	0.0	1.4	0.2	5.5	2.6	0.5	1.3	2.0	0.2
II.2.6	0.7	0.1	7.8	0.6	0.5	3.6	0.0	1.1	0.0	2.3	11.8	1.6	2.2	2.8	6.7	0.0
II.2.7	2.4	1.7	0.3	0.1	0.3	5.2	0.3	0.6	3.8	1.6	0.6	1.4	12.2	0.1	0.1	0.1
II.2.8	1.8	1.4	0.2	0.0	8.0	0.1	0.1	0.0	0.5	6.1	4.1	1.3	0.6	2.8	1.1	5.2
II.2.9	0.2	0.0	0.3	2.9	1.6	2.6	12.9	0.8	5.7	0.3	0.3	0.3	2.4	1.7	5.7	0.0
II.3.1	2.2	1.2	5.0	0.3	1.1	1.6	1.0	0.1	6.9	2.3	4.1	0.8	0.5	0.1	0.9	3.1
II.3.2	2.9	2.9	2.0	3.2	2.7	0.5	0.5	1.0	0.2	0.0	2.6	4.5	0.1	0.8	0.3	0.7
II.3.3	1.7	2.3	0.9	6.4	0.1	4.1	1.0	1.0	0.5	1.0	3.4	1.4	0.8	0.6	0.4	4.8
II.3.4	2.8	0.2	0.3	8.5	1.7	1.3	1.4	3.2	0.0	2.3	0.4	7.0	0.0	0.1	1.0	0.9
II.3.5	3.7	0.0	1.4	5.4	1.8	0.9	0.5	3.5	0.3	1.5	0.5	0.3	0.2	1.8	0.8	2.8
III.1.1	1.7	4.3	6.9	0.2	0.6	1.4	2.0	0.0	1.3	5.6	6.2	0.0	1.0	2.7	0.0	0.1
III.1.2	0.7	0.6	0.7	2.2	0.2	0.2	0.0	10.8	7.9	0.5	2.3	0.1	3.3	2.5	5.3	2.5
III.1.3	1.6	2.5	7.2	0.2	0.1	7.1	0.0	0.0	4.3	5.2	0.6	0.1	1.2	1.0	0.1	0.1
III.1.4	3.1	0.0	0.2	0.7	0.0	5.4	4.0	0.7	0.0	4.6	0.1	7.8	1.1	1.5	3.6	3.0
III.1.5	0.1	6.6	3.6	0.7	0.1	0.4	0.1	0.0	8.3	1.1	0.2	4.5	1.0	0.1	3.5	2.6
III.2.1	1.3	0.5	0.6	6.7	0.4	0.3	0.0	4.0	1.9	5.1	0.2	2.3	3.8	0.0	5.4	0.7
IV.1.1	0.3	1.1	12.4	0.0	2.5	0.3	2.1	0.0	2.2	5.2	2.1	2.5	2.3	0.2	2.9	0.3
IV.1.2	0.6	1.6	10.2	1.4	0.3	1.8	4.8	0.1	0.3	3.6	1.9	5.3	4.4	0.8	0.1	0.0
IV.1.3	0.7	0.0	2.1	1.7	4.3	4.7	4.0	8.1	0.2	0.1	0.5	0.0	0.1	4.8	1.9	6.5
IV.2.1	5.0	0.6	0.0	0.5	0.4	0.9	1.3	2.8	0.0	1.1	3.4	0.3	0.5	0.1	1.9	1.0
IV.3.1	0.7	2.9	0.1	0.2	3.5	0.0	0.4	1.4	0.7	3.8	2.4	4.6	1.7	0.5	4.0	11.5

Threats to validity

Several factors may restrict the generalizability of and limit the interpretation of our results. The first factor is related to the frequency and number of years the participants in the survey used the e-banking service; these two aspects could have affected the survey results. However, studying the influence of these two aspects on the survey results is outside the scope of this research. The second factor is related to the number of participants in the study. In our empirical study, we used a 0.05-statistical-significance threshold to show that the collected data provided sufficient evidence to allow us to draw the obtained results and conclusions. Although we considered only 118 survey participants, we found that, in most cases, the collected data were sufficient for obtaining statistically significant correlations and PCA results. It is true that collecting all responses in the same pool might be incorrect if the collected results were used to assess the e-service provided by the considered banks. However, this is not the case in our paper. In our paper, as explicitly stated herein, the collected results are used to study the correlations among the survey questions and investigate the range of considered aspects. Such investigation requires collecting data related to different banks and analyzing all of the collected data together; otherwise, the results might be

criticized for not being general enough. The third factor that could have affected the validity of the results is related to the fact that the analysis did not distinguish between the results that assessed the NFPs of different banks. To generalize the results, more participants with different experiences using e-banking services should be taken into account in similar large-scale evaluations. In addition, assessment data for each bank should be considered alone to allow for comparing the implementation of the NFPs in different banks. The forth factor that may affected the results is that we have assumed that users have in general a neutral experience in e-service. However, a user may have had a previous unpleasant experience that may affect his/her perception of the e-service, and hence the NFPs.

CONCLUSION AND FUTURE WORK

The proper identification of NFPs for e-services is expected to improve the quality of the services, and hence, the number of users who adopt these services will increase. NFPs of e-services must be identified early in the development process, while the functional requirements are also being developed. A comprehensive list of NFPs is presented in this paper. The identified properties are subsumed under four categories, namely, trust, user experience, quality of service, and conformance. The importance and relevance of each of these identified properties vary depending on the user's expertise and depth of domain and IT knowledge and on the e-service domain itself. For example, the privacy preservation property is obviously irrelevant for an e-service that requires anonymous users or no prior user registration. As we identified these NFPs, we attempted to capture all useful and critical properties. In practice, NFPs must be co-developed between the users and the developers to cover all of the desirable properties of the e-service. A case study in the e-banking service domain was presented in this paper.

There are two main outcomes of our research. The first outcome is to assess the NFPs for e-services and then classify them. The second outcome is the development of a useful web-based survey to reflect user perceptions in four categories of service NFPs or qualities identified in this research, namely, trust, user experience, quality of service, and conformance. The work presented in this paper is a landmark study on NFPs as viewed from e-banking service users. The goal of the tool proposed in this paper is to provide a better judgment for organizations when designing e-service in general and e-banking service in particular. Financial organizations will be able to provide improved service to their users and gain user trust, hence empowering e-banking service and online business. Service improvement will be aimed towards users' primary issues and requirements. The assessment tool is based on 50 questions that cover these four identified categories and the subcategories within. The questions were chosen to allow us to be as comprehensive and concise as possible without being excessive in number, with the aim of allowing the assessor to determine the true origins of any user dissatisfaction should it exist. As a result of applying this tool on a statistically representative sample of e-banking service users, the service provider will be able to identify weakness areas at the question level and develop a focused approach to enhancing service provision and delivery, ideally resulting in higher user satisfaction measured at a later date. In the case study, we learned that users were reasonably happy with e-banking services in the two categories of trust and user experience. However, the services were lacking in user satisfaction. We

also recommend that service providers use this tool periodically after deploying newer versions of their provided services.

We believe that as a result of more interactions with service end users, we will be able to confirm or refine our current findings and classification. Typically, a constraints section in the use case table description would include NFPs that are specifically related to that use case. Because this work can be tedious and time-consuming, automation tools to capture and manage NFPs can be developed and used.

In the future, we are planning to develop tools to capture and document these properties in other e-service domains, for example, in e-health and e-learning using the User Requirements Notation (Amyot, 2003; ITU-T 2003; Saleh and Al-Zarouni, 2004). Another interesting future research is the design of a tool to systematically elicit and capture the desirable NFPs according to the classification proposed in this paper.

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تقييم الخصائص غير الوظيفية للخدمات الإلكترونية

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الخـلاصة

تتكون الخصائص الوظيفية للخدمات الإلكترونية من الوظائف الملموسة في حين تتكون الخصائص غير الوظيفية للخدمات الإلكترونية من الصفات والميزات المرغوبة من قبل مستخدمي الخدمة لكنها غالباً تكون مخفية وغير ظاهرة. يقوم مستخدم الخدمة بالتعبير عن هذه الخصائص (غير الوظيفية) رسمياً لمطوري الخدمة ثم يقوم مطوري الخدمة بتحويلها إلى متطلبات غير وظيفية. وكثيراً ما يغفل مطور الخدمة الإلكترونية عن الخصائص الوظيفية أو تضاف إلى الخدمة في وقت لاحق. ونناقش في هذا البحث سبل تحديد الخصائص غير الوظيفية للخدمات الإلكترونية كجزء من متطلبات المرحلة الهندسية في دورة حياة تطوير البرمجيات الإلكترونية. وللمساعدة في التقاط الخصائص غير الوظيفية قدمنا تصنيف شامل لهذه الخصائص على أساس أربع فئات: الثقة، تجربة المستخدم، جودة الخدمة والمطابقة للمعايير. ثم استخدمنا هذا التصنيف لوضع أداة لتقييم الخصائص غير الوظيفية للخدمات المصرفية عبر الإنترنت. نتائج الدراسة موضحة في هذا البحث.