Evaluating the Utility of Human-Machine User Interfaces Using Balanced Score Cards

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Abstract. Evaluating the utility of Human-Machine Systems' User Interfaces is not trivial. Several evaluation methods can be used to investigate if the behaviour of the user interface complies with best practices of Human-Machine Interface Design. Even when is possible to agree on which methods to use to conduct the evaluation, defining the utility requires evaluating the interface under analysis toward the company's goals, or mission. This paper investigates how the utility, perceived by end users of interfaces, can be captured by a research instrument, as well as be represented by a structured approach based on Usability evaluation and Balanced Score Cards methodology. This is an alternative demarche for accessing the Usability of a Software System, and the main goal is helping designers and administrators to maintain and improve their systems.

Keywords: Usability · Balanced scorecards · Interactive systems · User interfaces

1 Introduction

Today, universities' libraries provide websites for consulting information, which can be referred to as User Interface [1] of a Human-Machine System, i.e., a computer system that supports interaction between humans and computers. When websites are designed according to the best practices in the engineering of Human-Machine Systems, they can be valuable tools for its users, fulfilling their needs and expectations, assisting them in accomplishing their tasks with the system. Consequently, providing a well designed website is of major importance for Companies and Universities, which seek supporting their strategic goals. Different aspects can be considered for determining if a website is well designed, such as reliability and security, for instance [2]. However, when evaluating from the user point of view, usability is an important aspect to consider [3, 4], especially when the web usability evaluation methods and techniques are grouped among those requiring end user participation. Therefore, this work focus on evaluating a library website according to usability aspects, with end user involvement, which are often university staff, such as professors, researchers and students. According to [3], end users of library websites have high expectations on respect to its performance when they are carrying particular tasks, with especial attention to how easy is to use it, how efficient is the outcome, and finally how satisfied they are. Even when a website is

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evaluated against the constructs mentioned hitherto, a company/university designer might find it challenging measuring the level of utility of the resource. That is, to provide quantified evidence that the usability evaluation constructs (e.g., usefulness, satisfaction, effectiveness, or efficiency) are perceived toward the company's goals, or mission.

In this paper we propose the use of *Balanced Score Cards* (BSC), to monitor and follow the utility of the systems whose user interface needs being constantly evaluated and improved (e.g., library websites). The Balanced Scorecards method is a multidimensional approach that takes advantage of the multiplicity of information resources existing today, to provide an expanded view of company's values and align them with their internal processes. Consequently the contribution of this paper is to provide a structured approach to assess the perceived utility of a user interface. In order to achieve that we addressed the following research question: what is the level of perceived utility of the library website by end users, according to usability assessment?

To help answering the research question, the perceived usability of a library website is investigated with the assistance of a research instrument based on three underlying concepts, namely Effectiveness, Efficiency and Learnability as well as Balanced Scorecards. The rest of this paper is organised as follows: Sect. 2 addresses the underlying theory that supports Usability Testing and Balanced Scorecards, Sect. 3 presents the design of the research as well as information about research goals, Sect. 4 presents information about the Evaluation the Usability of a User Interface with BSC, Sect. 5 presents the findings, and considerations about the limitations of the research, and, finally, Sect. 6, presents conclusions and future work.

2 Related Work

Usability is accounted as one of the several assessment tools available the Software Engineering tool's belt for evaluating User Interfaces of computer systems, *Human-Machine Interaction* (HMI) community continuously contribute for the activity in the research field, e.g., coining different yet complementary definitions for the term. For Nielsen Usability is a quality attribute, measuring user interfaces easiness level [5]. This is supported by [6], whose work reveals positive correlation between Usability and Quality. Standards and regulations might provide their own definitions, e.g., ISO 9241-11 considers tree constructs when evaluating a specified product's context of use, namely Effectiveness, Efficiency and Satisfaction [7]. Still in the context of ISO 9241-11, Effectiveness refers to the completeness at which users achieve specified goals; Efficiency refers to the resources used in completing a task; and Satisfaction reveals positive attitudes toward using the system. When considering the model for the framework used as research instrument, we noticed that the literature provides evidence of strong positive correlation between Satisfaction with Effectiveness and Efficiency [8]. Due to these findings, the construct of Satisfaction was excluded from the framework used as research instrument. Instead of Satisfaction, the construct of Learnability is selected as part of the research instrument. This construct is based on Software Engineering aspects, such as the usability model proposed by Nielsen in the early 1990 [9], referring to as the capability of systems being easy to use by casual

users [10], or ISO/IEC 9126 [11], referring to as the capability of software products to make possible that users learn how to use it. Learnability is identified in several studies as fundamental characteristic for Usability [10, 12–14].

Web usability evaluations are generally performed with and without end user participation. After the process is performed, and the system design is consequently improved, a company/university might find difficult to measure the level of utility of the resource. That is, to provide quantified (cardinal) evidence that the usability evaluation constructs (e.g., Usefulness, Satisfaction, Effectiveness, or Efficiency) are perceived toward the company's goals, or mission. The construct of Utility might have a continuum of possible conceptualisations, as observed by [15], often tied to subjective preference for particulars. Therefore, is necessary to establish a common ground, such as the definition of utility provided by Jacob Nielsen [9], which suits computer software design applied to web design. In his definition, utility means the match between task requirements and product functionality, or the ability of the system to help the user carry out a set of tasks [16]. The presentation of Utility information can make use performance indicators. Due to the increasingly business competitiveness, the evaluation of performance in business environments, which is a topic of research that has been received great attention over the years, has lead to the adoption of *Management Information Systems* (MIS). While MIS provide important resources for decision-making, control, analysis and visualisation of information regarding the company and its processes, they also creates new management challenges, namely the ability to understand the new decision models and their methods [17]. The use of indicators of performance in MIS supports manager's decision-making processes. Indicators have the potential to cooperate with the company's view alignment and processes organisation around their goals.

Some researchers have concerns about the impact of such indicators in the management of companies, claiming that traditionally they are built on the top of financial information, and therefore, provide few hints about other processes [17]. Others consider the importance of using non-financial indicators (e.g., customer relationships, organisational culture) when evaluating the business performance [18]. Apart from that discussion, managers still have difficulties on the necessary methodology to deal with such kind of indicators and advance for the need of solutions that might correlate complex issues such as flexibility, accuracy or speed, in simple but meaningful number. Kaplan and Norton have investigated how to improve the concept of control system with information beyond the traditional financial dimension [17]. As result, in the early 90s they developed the BSC framework. They were interested in indicators that summarized information such as i) financial and non-financial, ii) internal and external, iii) business performance and iv) current results and future of the company, which could link the company's goals with well-defined strategy, one that can help employees to achieve the goals through concrete actions. BSC can be considered a structured approach to evaluate the performance and enforce the company's vision and mission, by agreeing in perspectives and measures that are monitored individually. The following processes are implemented to obtain information using BSC (Fig. 1):

- Process to convert the vision: it allows for the management team to obtain a consensus in terms of the company's vision and strategy.

- Process of communicating and bonding: it allows for the management team to communicate the company's vision and strategy in order that they bond it to the personal and individual objectives.
- Process of business planning: it allows the companies to plan about their plan of action and resources.
- Process of strategic learning: it allows the companies to perform strategic learning.

The company's strategies are converted into BSC components, such as strategic objectives, indicators, goals and action programs, which are the depth of the analysis, usually represented in four perspectives. Each perspective of analysis should provide indicators, which are measured according to a measurement scale defined according to the process.

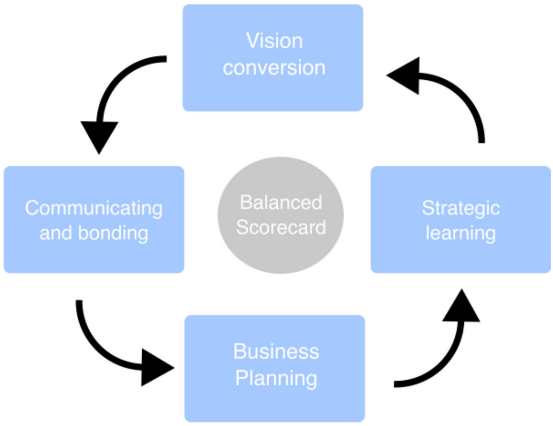

Fig. 1. Processes in BSC [17].

According to [17], BSC (usually) supports four perspectives, namely Resources, Community, Internal Processes and Personal. Figure 2 illustrates how the perspectives correspond to the strategic view.

BSC constitutes into a multidimensional approach, one that assist companies in adopting a wider spectrum of analysis of their internal processes, providing an expanded view of its values, aligned with such processes. Evidence of the benefits for using BSC in the field of software engineering is provided by [18], who evaluated the utility of a Data Warehousing System.

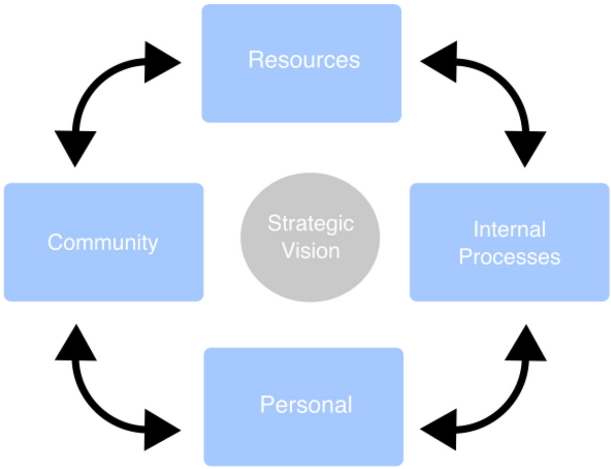

Fig. 2. Template dimensions in BSC framework [17].

3 The Evaluation Approach

A. *Research Goals and Object of Research*
The present research investigates the perceived utility of a library website through the Usability constructs of Effectiveness and Efficiency, according to ISO 9241-11 [7], as well as through the construct of Learnability, based on the Usability Model proposed by Nielsen [10]. The object of research in question, i.e., the library website, is a service that makes possible for end users to conduct bibliographic research in different databases, such as the university's thesis and dissertations, as well as in other databases available for the academic community. The library website is mainly targeted for students, researchers and university staff. The participants that we have addressed in this research are part of two groups, namely students and researchers (Table 1).

Table 1. Characteristics of the respondents.

Characteristic	Category	Freq.	%
Gender	Female	7	20%
	Male	28	80%
	Prefer not declare	–	–
Age	18–24	30	86%
	25–30	2	6%
	31–40	2	6%
	41–50	–	–
	51–60	1	3%

(*continued*)

Table 1. (*continued*)

Characteristic	Category	Freq.	%
Status	Graduation/master student	33	94%
	PhD student	2	6%
	Professor/researcher	–	–
Level of computer skill	Intermediate level	5	14%
	Advanced level	19	54%
	Expert level	11	31%
Use frequency -	Daily or almost daily	35	100%
	Once or twice a week	–	–
	Once or twice a month	–	–
	Once or twice a year	–	–

We decided to design our research instrument in the form of a survey, which is used to collect necessary data to analyse. The survey uses closed questions to collect the information, as opposed to open-ended questions, which the responder is free to provide his/hers own answers to the questions. In this case, we rely on the Likert scale to transform order points into a linear scale [19] to address two groups of information:

1) Demographic information, also referred to as filter questions, enabling to explore the characteristics of the different study groups;
2) Research questions information, also referred to as usability evaluation instrument, directly related with the usability evaluation model in the context of academic libraries, proposed by [12].

Usually the scale rating ranges from 5, 7 and 9 points. We decided to design our instrument using the 7 points scale, as we can see in Table 2. The research survey is designed to collect information in a monthly basis periodicity. The measurement framework is presented in Table 3.

Table 2. Likert Scale defined for the research instrument [19].

(1) I strongly disagree	(2) Disagree	(3) Slightly disagree	(4) I do not agree or disagree	(5) Slightly agree	(6) I agree	(7) I totally agree
(Do not answer at all to the required)	(Serves with failed the minimum required)	(Meets partially below the expectations)	(Neither agree or disagree)	(Meets partially above the expectations)	(Meets completely the expectations)	(Above the expectations)

B. *Interface Evaluation Process*
The web software *BSC Designer* is used for implementing the BSC. It allows the implementation of strategic maps, strategic objectives, indicators, data entrance and normalisation of data. The data visualisation is possible by the means of several graphical representation elements, such as dashboards, graphics (e.g., pie, bar, etc.). The data for analysis is collected using the instrument research previously identified.

The word 'usability' refers to methods for improving ease-of-use during the design process. It is based on human psychology and user research and in general refers to the quality of the interaction between the user (human operator) and the system being operated, where a set of factors such as time taken to perform tasks, errors made during the interaction, among others, might be considered [20]. The causal framework usability (depicted in Fig. 3) proposed by [21] intends to highlight the multiplicity of usability constituents, or guidelines and standards for web design [22]. As the usability of a system has the potential to impact how the user accomplishes his/her tasks with the system, it is relevant to use all methods and tools to understand its underlining complexity and subsequently improve the interactive system's user interfaces.

Table 3. Measurement framework

Category	Attributes	Method	Metric (%)	Measurement scale	Value
Characteristics of the respondents	Gender	Research survey	Gender	F/M/ND	1 (Female), 2(Male), 3 (Prefer not declare)
Characteristics of the respondents	Age	Research survey	Age category	5-point	1 (18–24), 2 (25–30), 3(31–40), 4(41–50), 5 (51–60)
Characteristics of the respondents	User status	Research survey	Status	3-point	1 (Graduation/Master Student), 2 (PhD Student), 3 (Professor/Researcher)
Characteristics of the respondents	User level of computer skill	Research survey	Level of computer skill	3-point	1 (Intermediate level), 2 (Advanced level), 3 (Expert level)
Characteristics of the respondents	Frequency of computer's use	Research survey	Frequency of computer's use	4-point	1 (Daily or Almost Daily) 2 (Once or Twice a Week) 3 (Once or Twice a Month) 4 (Once or Twice a Year)
Effectiveness	Six questions related to the construct	Research survey	Level of general effectiveness	7 point	1 (I strongly disagree), 7 (I totally agree)
Efficiency	Six questions related to the construct	Research survey	Level of general efficiency	7 point	1 (I strongly disagree), 7 (I totally agree)
Learnability	Six questions related to the construct	Research survey	Level of general learnability	7 point	1 (I strongly disagree), 7 (I totally agree)

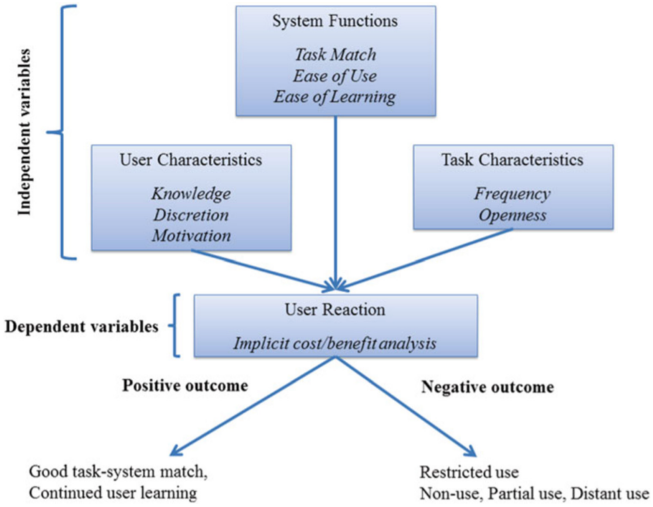

Fig. 3. Usability causal framework by [21].

The literature reported several methods [23] to verify the perceived usability level of a system, namely the questionnaire for User Interface Satisfaction (QUIS) [24], the computer System Usability Questionnaire (CSUQ) [25], the system Usability Scale (SUS) [26], Words, adapted from Microsoft's Product Reaction Cards [27], Website usability evaluation questionnaire [28], or the Usability Evaluation Model in the context of academic libraries [12]. To support the research variables from the perspectives for the BSC, we chose using the Usability Evaluation Model and associated evaluation survey tool proposed by [12], tailored to academic libraries websites.

4 Using Balanced Scorecards

As BSC presents a multidimensional approach that helps the practitioner to consider a wide variety of aspects in the evaluation of the company's mission, we consider it for supporting the evaluation of the utility of User Interfaces of interactive systems, which has the potential to improve the level of task accomplishment from the user with the referred system. Figure 4 depicts the strategic map defined for the BSC, which identifies the relationships between the perspectives and the strategic objectives.

The initial design approach for the BSC perspectives is based on four perspectives, namely *Financial, Client, Internal Processes* and *Learning and Growth.* However, Kaplan and Norton suggest that those perspectives should be used as a template, not as a strait jacket. In this sense, this work defines three perspectives that we believe are sufficient to translate our mission, namely the perspectives of Community, Internal Processes, and Learning and Growth (Fig. 4) (Table 4).

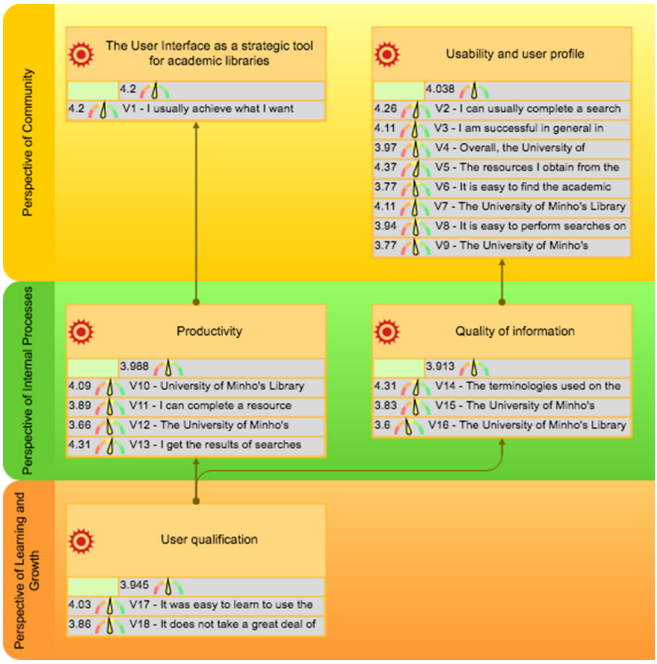

Fig. 4. The BSC strategic map with indicators defined for this project. Adapted from BSC designer.

In the perspective of Community, two strategic objectives are defined, along with their indicators and objectives, in order to attest the level of coupling between system and modelled processes, as well as to verify the user's difficulties of utilisation, respectively. In the perspective of Internal Processes, two strategic objectives are defined, along with their indicators and objectives, for verifying the level of user's productivity, as well as to verify the user's perception of system information. The perspective of Learning and Growth has one strategic objective defined, along with its indicators and objective, having the goal to check user's qualification level.

Table 4. Description of the Perspectives and strategic objectives.

Strategic objectives	Indicators	Objectives
Perspective of community		
The user interface as a strategic tool for academic libraries	Decision-making process	Increase the importance of the User Interface for the Universities
Usability and user profile	Task completeness	Decrease the difficulties of utilisation
	Information findability	
	Overall usefulness	
	Usefulness of resources	
	Easiness of resources	
	General usability	
	Easiness of task	
	Understandability of menus	
Perspective of internal processes		
Productivity	Coverability of topics	Increase level of user's productivity
	Quickness of task completion	
	Design satisfaction	
	Quickness of results presentation	
Quality of information	Understandability of terminologies	Decrease time of user recovering from errors
	Availability of help functions	
	Information organisation	
Perspective of learning and growth		
User qualification.	Learnability level	Increase user qualification
	Training level for initial use of system	

5 Result Analysis

The overall given value for the variables are composed by the pair [order point/representation in the linear scale], in which the order point is obtained by verifying the *mode* value of each research topic, and the representation in the linear scale can be obtained by consulting Table 2. In the first strategic objective of the "Perspective of Community", we verify the user perception about the User Interface as a strategic tool for academic libraries. The value measured for the variable V1 is

presented in the Table 5. This intends to measure the user perception about task achievement using the user interface in question. Nielsen highlights that the ability of user's completing tasks are a relevant indicator of success rates. In this sense, the result indicates that users "*Neither agreeing or disagreeing*" on the UI supporting their decision-making processes (Support for decision-making process indicator).

Table 5. Topics of the strategic objective "The User Interface as a strategic tool for academic libraries".

Variables	Topics	Overall average	Overall average for strategic objective
V1	I usually achieve what I want using the University of Minho's Library web site	4,0	4,0

The "Usability and user profile" strategic objective presents an enlarged number of topics, aiming to verify the user's perception of usability aspects. The values measured for the variables V2 to V9 are presented in the Table 6. Those variables measure how the system's usability meets their expectations. Users reported "*Neither agreeing or disagreeing*" on the variables V5 and V4, which investigates the perception of usefulness of the website (Overall usefulness and Usefulness of resources indicators). The literature frequently correlates lack of usefulness with low user adoption. About a general level of facility for finding resources, users reported "*Neither agreeing or disagreeing*" on variables V3 and V8 (Information findability and Easiness of task indicators) and "*Meets partially above the expectations"* on variable V6 (Easiness of resources indicator). This is one of the most relevant measurements in usability, and is frequently correlated with quality design of products. In general, users "*Neither agree or disagree*" on the General usability indicator (V7). On V9, users report "*Neither agreeing or disagreeing*" in the facility to understand the website menus (Understandability of menus indicator). Menu Design is a relevant topic, which presents guidelines for good design for helping users to find content and features. Along with accuracy, completeness helps to evaluate how effective the user goals can be achieved. In variable V2, users reported "*Neither agreeing or disagreeing*" on the Task completeness indicator, about success on completing a search task using the investigated website.

Table 7 present the topics of the "Productivity" strategic objective. Variables V11 and V13 are concerned with aspects about the speed of achieving a certain goal, which is frequently correlated with efficiency in the literature. Users accounted "*Neither agreeing or disagreeing*" for Quickness of task completion indicator and "*Meets partially above the expectations"* for Quickness of results presentation indicator.

Table 6. Topics of the strategic objective "Usability and user profile".

Variables	Topics	Overall average	Overall average for strategic objective
V2	I can usually complete a search task using the University of Minho's Library web site	4,0	4,0
V3	I am successful in general in finding academic resource(s) using the University of Minho's Library web site	4,0	
V4	Overall, the University of Minho's Library web site is useful in helping me find information	4,0	
V5	The resources I obtain from the University of Minho's Library web site are usually useful	4,0	
V6	It is easy to find the academic resources that I want on the University of Minho's Library web site	5,0	
V7	The University of Minho's Library web site is easy to use in general	4,0	
V8	It is easy to perform searches on the University of Minho's Library web site	4,0	
V9	The University of Minho's Library web site offers easy-to-understand menus	4,0	

Variable V12 investigates the design of the website in question, and is indeed a difficult topic for the casual, non-designer user, to evaluate. Respondents reported "*Neither agreeing or disagreeing*" on the Design satisfaction indicator. Coverage of topics is a relevant topic for any university's library, since its main mission is to deliver a wider range of information for its selected and highly exigent public. In the variable V10, users reported "*Neither agreeing or disagreeing*" that the website covered sufficient topics based on their exploration (Coverability of topics indicator).

In Table 8 we can see the information related to the "Quality of Information" strategic objective. As part of a good user experience with any user interface, documentation resources such as user Manuals, Reference Sheets, and Help Functions directly in the User Interface might be provided for users, containing appropriate terminologies for the website's audience. Variables V14 to V16 investigates the user perception about the terminologies used in the website and available help functions. Respondents declared "*Neither agreeing or disagreeing*" on indicators 'Understandability of terminologies', 'Availability of help functions' and 'Information organisation'.

Table 7. Topics of the strategic objective "Productivity".

Variables	Topics	Overall average	Overall average for strategic objective
V10	University of Minho's Library web site usually covers sufficient topics that I try to explore	4,0	4,0
V11	I can complete a resource finding task quickly using the University of Minho's Library web site	4,0	
V12	The University of Minho's Library web site is well designed to find what I want	4,0	
V13	I get the results of searches quickly when using the University of Minho's Library web site	5,0	

Next, in Table 9, we present the topics of "User qualification" strategic objective. Variables V17 and V18 investigates user perception about the level of facility to learn and become proficient with the universities' website. This is a relevant aspect of usability. Products (e.g., websites) that are easy to learn are frequently considered easy to use. Users reported "*Neither agreeing or disagreeing*" on both website being easy to learn (Learnability level indicator) and demanding few effort to become proficient (Training level for initial use of system indicator), respectively.

Table 8. Topics of the strategic objective "Quality of information".

Variables	Topics	Overall average	Overall average for strategic objective
V14	The terminologies used on the University of Minho's Library web site are easily understandable	4,0	4,0
V15	The University of Minho's Library web site has appropriate help functions	4,0	
V16	The University of Minho's Library web site provides well-organized help information for new users	4,0	

BSC methodology enables frequent data input for each variable measurement, which makes possible continuously monitoring the selected topics. For the evaluated period, users report "*Neither agreeing or disagreeing*" on the perceived utility of the website, according to the presented model, which allows the achievement of the main goals of this paper.

Table 9. Topics of the strategic objective "User qualification".

Variables	Topics	Overall average	Overall average for strategic objective
V17	It was easy to learn to use the University of Minho's Library web site	4,0	4,0
V18	It does not take a great deal of effort for new users to become proficient with the University of Minho's Library web site	4,0	

Although this research is applied for a number of academic members, we understand that involving more categories other than students and researchers among the universe of respondents (e.g., university staff, library and department employees, etc.) would have the potential to increase not only the size of the sample but also to increase the spectre of opinions. Collecting information from enlarged representative group would have the potential to increase the feedback regarding the usability aspects that were considered, and even consider different aspects that need to be investigated. The same could apply to extend the participation for members of different courses at the university.

6 Conclusions and Future Work

With the increasingly number of users, companies that relies their processes in websites need accurate, reliable and quick feedback about their working. This paper investigated how the perceived utility of those websites can be captured by a research instrument, as well as be represented by a structured methodology, intending to help system designers and administrators to maintain and improve their systems. We achieved the proposed goals of this paper, by providing evidence that the level of utility of a website perceived by users can be verified in terms of Effectiveness, Efficiency and Learnability. We also provided evidence that the BSC methodology is able to provide quantified (cardinal) evidence about the utility of the website in question, captured by the research instrument.

Future improvements in this research include using an automated instrument of analysis, in a way that the results can be updated automatically within a shorter period of time, as well as increase the universe of responders. As selecting the best indicators from the Engineering of User Interfaces is also hard work, future improvements in the research model with more relevant investigation keys might support the investigation of other relevant questions. Another possibility would be to investigate another type of user interface, such as in critical systems. The usability investigation of the University of Minho Library website was responded by a public composed by 94% of graduation/master students, which declared daily or almost daily computer's use frequency, 54% of them claiming to possess advanced level of computer knowledge (Informatics/Computer Science field). Small recommendations can be made to reinforce the items variables V12 and V16 (Design satisfaction and Information

organisation indicators). In general they account for providing well-organized help information for new users and for the web site being well designed to find the information users are seeking.

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