A Methodology for Evaluating PSI e-Infrastructures Based on Multiple Value Models

C. Alexopoulos, E. Loukis, Y. Charalabidis, I. Tagkopoulos
Department of Information and Communication Systems Engineering
University of the Aegean
83200 Karlovasi, Samos, Greece
alexop@aegean.gr, e.loukis@aegean.gr, yannisx@aegean.gr, icsdm10017@icsd.aegean.gr

Abstract — **The trend of opening government data, in order to be used for scientific, commercial and political purposes, has resulted in the development of numerous e-infrastructures providing public sector information (PSI). The big investments that have been made in this direction necessitate a deeper understanding and assessment of the value they produce. This paper presents a methodology for evaluating PSI e-infrastructures, which is based on the estimation of multiple value models corresponding to their main stakeholder groups: data users and data providers. Each value model consists of several value dimensions and their corresponding value measures, organized in three levels (associated with efficiency, effectiveness and future behaviour), and also the relations among them. The proposed methodology allows a comprehensive assessment of the various types of value generated by a PSI e-infrastructure for each stakeholder group, and also the interconnections among them. This enables a better understanding of the whole value generation mechanism and a rational definition of improvements priorities.**

Keywords-evaluation: open government data; public sector information (PSI); e-Infrastructures, evaluation; value model.

I. INTRODUCTION

Innovation, the foundation of modern economic activity and development, relies critically on rapid scientific advances, which increasingly necessitate extensive ICT-based cross border research collaboration and use of huge high-capacity computing resources; this necessitates the development of ICT infrastructures for supporting this new paradigm of e-Science, also referred to as scientific 'e-Infrastructures' [1] or 'cyber infrastructures' [6]. They include high performance grid computing aiming to support simulations and analyses of large volumes of data. They also include tools to support collection, storage, analysis, and modeling of data [5]. Scientists also use these e-infrastructure to share data with others, and to support wide scientific collaboration [9], using various tools, ranging from simple email and mailing lists, to more advanced collaborative applications such as wikis. This new e-Science paradigm is defined as "scholarly and scientific research activities in the virtual space generated by the networked computers and by advanced information and communication technologies" [7]. The basic idea about e-Science is that knowledge production will be enhanced by the combination of pooled human expertise, data and sources, and computational and visualization tools [8].

At the same time, governments around the world release raw government data to their citizens at an increased pace, in order to be used for scientific, commercial and political purposes. As government data are defined all the information that public bodies produce, collect or pay for, such as geographical information, statistics, weather data, data from publicly funded research projects, etc. [2]. This large amount of data is very useful for conducting scientific research in many areas in the social, political, economic, administrative, and management sciences. The conclusions of this research can be very useful for government as they enable a better understanding of social and economic problems, and also of the effectiveness of various policies government agencies implement for addressing them. Furthermore, these data have a significant — currently untapped — potential for re-use in new products and services. Overall economic gains from opening up this resource could amount to about € 40 billion a year in the EU [2], [4]. Opening up public data will also foster the wider participation of citizens in political and social life, and improve the quality and effectiveness of political debate.

However, the realization of the above important benefits necessitates the deployment and use of advanced e-Infrastructures, incorporating distributed and diverse public sector information resources as well as data curation, semantic annotation and visualization tools, capable of supporting scientific collaboration and governance related research, while also enabling the development of new value-added e-services. This has lead to the big investments by numerous government agencies for the development of e-infrastructures providing public sector information (PSI). Many international projects are in progress in this direction, funded by various international institutions, such as the ones of the European Union.

This necessitates a systematic evaluation of these PSI e-Infrastructures, aiming at a better understanding and assessment of value they generate. However, a structure and comprehensive evaluation methodology is missing. This is understandable if we take into account that PSI e-infrastructures have very recently emerged and are currently making the first steps. An additional difficulty is that they are used by two main groups of stakeholders: the data providers (who provide datasets concerning various thematic areas) and data users (who use these data for various scientific, commercial and political purposes). Therefore a comprehensive methodology for evaluating PSI e-infrastructures should incorporate the viewpoints of both these stakeholders groups.

This paper contributes to filling this gap by presenting a methodology for evaluating PSI e-infrastructures, which is based on their capabilities and objectives, and also on previous relevant research. The proposed methodology includes initially the definition of one value model for each stakeholder group, which consists of the main dimensions of value the PSI e-infrastructure generates for it, and also the connections among them. These value dimensions are organized in three value levels associated with efficiency (= quality of the various capabilities provided to the particular group), effectiveness (= degree of supporting this group for achieving its objectives) and users' future behavior respectively. Also, for each value dimension a number of measures are defined. Using data collected from users of the PSI e-infrastructure under evaluation these value measures and dimensions are assessed, and also the relations among them are estimated. The proposed evaluation methodology allows a comprehensive and structured assessment of the various types of value generated by a PSI e-infrastructure for each stakeholder group, and also the interconnections among them. This enables a better understanding of the value generation mechanism and at the same time a rational definition of improvement priorities.

In the following section II the background of the proposed methodology is outlined. Then in section III the definition of the two value models for the data users and the data providers is presented, while in section IV the value models estimation algorithm is described. Finally in section V the conclusions are summarized and future research directions are proposed.

II. Background

In order to develop a methodology for evaluating PSI e-Infrastructures we can use frameworks and elements from previous in the areas of information systems (IS) evaluation (section II.A), technology acceptance and information systems success models (section II.B), and e-services evaluation (section II.C). Furthermore, it is necessary to take into account the capabilities and objectives of modern PSI e-infrastructures (section II.D).

A. *Information Systems Evaluation*

There is long and extensive research on the evaluation of IS [10] – [19], which has revealed its inherent difficulties. The major conclusion of this research is that evaluation is a highly complex task, mainly because of the multi-dimensional benefits and value created by most categories of IS. IS's offer various types of benefits, both financial and non-financial, and also tangible and intangible ones, which differ among the different types of IS. So, it is not possible to formulate one generic IS evaluation method, which is applicable to all IS; each different type of IS has different objectives, therefore it requires different types of evaluation methods and measurements, taking into account its particular characteristics, objectives and expected benefits. Smithson and Hirscheim (1998) distinguish between two basic approaches to IS. The first approach is 'efficiency-oriented' as it evaluates IS performance with respect to some predefined technical and functional specifications, and focus on answering the question of whether the IS is doing things right. The second approach is 'effectiveness-oriented', as it evaluates to what extent the IS supports the execution of business-level tasks or the achievement of business-level objectives. Therefore a comprehensive methodology for evaluating a particular type of IS should include evaluation of both its efficiency and its effectiveness, taking into account its particular characteristics, capabilities and objectives.

B. *Technology Acceptance and IS Success Models*

Extensive research has been conducted in order to identify the characteristics and factors affecting the attitude towards using an IS, the intention to use it and finally the extent of its actual usage, which has lead to the development of the Technology Acceptance Model (TAM) and its subsequent extensions [20] – [23]. The TAM has been based on the Theory of Reasoned Action (TRA) [24] and the Theory of Planned Behavior (TPB) [25]. It posits that perceived usefulness and perceived ease of use determine an individual's intention to use a system with intention to use serving as a mediator of actual system use; perceived usefulness is also seen as being directly impacted by perceived ease of use. There have been many attempts to extend TAM, which have generally taken one of the following three approaches: by introducing additional factors from related models, by introducing additional or alternative belief factors, and by examining antecedents and moderators of perceived usefulness and perceived ease of use [26]. The most widely used extension of TAM has been the 'Unified Theory of Acceptance and Use of Technology' (UTAUT) [21], which posits that the four key factors that determine technology usage intension are performance expectancy (similar to the usefulness of the TAM), effort expectancy (similar to the ease of use of the TAM), social influence, and facilitating conditions.

Another research stream that can provide useful elements is the IS success research [27]-[29]. The most widely used IS success model has been developed by DeLone and McLean (1992). It proposes seven IS success measures, which are structured in three layers: 'information quality', 'system quality' and 'service quality' (at the first layer), which affect 'user satisfaction' and also the 'actual use' of the IS (at the second level); these two variables determine the 'individual impact' and the 'organizational impact' of the IS. Seddon [29] proposed a re-specification and extension of this model, which includes perceived usefulness instead of actual use. This research stream suggests that IS evaluation should adopt a layered approach based on the above interrelated IS success measures (information quality, system quality, service quality, user satisfaction, actual use, perceived usefulness, individual impact and organizational impact) and on the relations among them. This focus not only on the above IS value measures, but also on the relations among them, can be very useful for the formulation of methodologies for evaluating various types of IS.

C. E-Services Evaluation

The emergence of numerous internet-based e-services (e.g. information portals, e-commerce, e-banking, e-government, etc.) leads to the development of many frameworks for evaluating them [30] – [34]. Extensive reviews of this research are provided in Rowley [30] and Sumak et al. [31]. These frameworks suggest useful e-services evaluation dimensions and measures. Most of them assess the quality of the capabilities that the e-service provides to its users. Some others assess the support it provides to users for performing various tasks and achieving various objectives, or users' overall satisfaction. However, most of the above frameworks do not include advanced ways of processing the evaluation data collected from the users, in order to maximize the extraction of value-related knowledge from them. They include mainly simple calculations of average values for all evaluation measures and dimensions over all the users who evaluate the e-service; the relations among the proposed evaluation dimensions and measures, which could form the basis for advanced multi-dimensional statistical analysis, are not exploited all for drawing more conclusions and insights.

Only recently some research in this direction has been conducted. In [3] is proposed and verified a structured methodology for assessing and improving e-services, which is based on the estimation of value models of them. Such a value model consists of a set of measures assessing different types of value generated by the evaluated e-service, and the relations among them. These value measures are organized in three levels:
(i) Efficiency level: it includes 'efficiency' measures, which assess the quality of the basic capabilities offered by the e-service to its users,
(ii) Effectiveness level: it includes 'effectiveness' measures, which assess the extent of use of the e-service and also its outcomes (e.g. to what extent the e-service assists the users for completing their tasks, achieving their objectives, offers them fun and enjoyment, or in general satisfies them),
(iii) Future behaviour level: it includes measures assessing to what extent the e-service influences the future behaviour of its users (e.g. to what extent they intend to use the e-service again in the future, or recommend it to friends and colleagues)

This methodology combines assessment of these multiple types of value generated by the e-service with estimation of the relations among them (with the former and the latter constituting the value model of the e-service), and also an algorithm for defining priorities for capabilities' improvements. Such an approach would be useful for the development of a comprehensive methodology for evaluating PSI e-Infrastructures. However, an extension of this approach is required, since as mentioned above PSI e-Infrastructures have two distinct stakeholders groups, the data providers and the data users, so it is necessary to estimate one value model for each of them.

D. Capabilitiesof PSI e-Infrastructures

The capabilities that a modern PSI e-Infrastructure should offer have been analysed as part of the ENGAGE research project (http://www.engage-project.eu) on PSI e-Infrastructures, which is partly funded by the European Commission. The main goal of this project is the development and deployment of a data infrastructure, incorporating distributed and diverse public sector information resources, capable of supporting scientific collaboration and governance-related research from multi-disciplinary scientific communities, and also providing open governmental data towards citizens.

Based on ENGAGE experience and research such platforms consist of usually three main functional areas supporting Data Acquisition, Data Provision and Communication. In particular:
- *Data Acquisition:* it provides all the necessary utilities and functions for acquiring data from government agencies. It enables a government agency to upload a dataset or to Sregister a link to a dataset. Such a platform usually provides an Application Programming Interface (API) for performing the above tasks. Also, it provides capabilities for improving the quality of a dataset before uploading it, through cleansing, transformation and enrichment.
- *Data Provision:* it provides all the necessary utilities and functions for offering public sector data to its users. A user could search catalogs of datasets with different ways, such as free-text, structured criteria, browsing into sub catalogs, map search or using a sparql endpoint, and also download datasets. The platform also provides an API for performing the above tasks. It also provides capabilities for data visualization, which is the process of representing data, information or knowledge in a way that will facilitate and enhance understanding. Visualization is extensively used in science, education, business, communication and other fields to help practitioners comprehend and communicate complex, overwhelming or unfamiliar information. Furthermore, capabilities for data analysis are also provided.
- *Communication:* utilities and functions for communication between data providers and data users, and also among data users. They enable data providers to gather user feedback (e.g. comments, ratings, further needs) and usage statistics for each of the uploaded datasets. These are also visible by all users (e.g. a user can see other users' comments and ratings on a dataset before deciding to download and use it), leading to the establishment of a 'reputation management system'.

III. Value Models Definition

Based on the background presented in the previous section a methodology for evaluating PSI e-Infrastructures was developed, which involves a big variety of value measures assessing many different aspects of the value these platforms generate, and also advanced processing of users' evaluation data in order to maximize the value-related knowledge extracted from them. It combines efficiency and effectiveness evaluation dimensions and measures from several existing frameworks, adapted to the particular objectives, characteristics, resources and capabilities of PSI e-infrastructures. The proposed methodology, extending the approach of [3], is based on the estimation of two value models of a PSI e-Infrastructure, one for each of the main stakeholders groups: data users and data providers. In this section is described the definition of these two value models, while in the following section is described the algorithm for estimating them based on users' evaluation data.

Each of these two value models consists of the main dimensions of the value that the PSI e-infrastructure generates for the corresponding stakeholders group, and the connections among them. These value dimensions are organized in three value levels, adopting the structure proposed by [3], which focus on efficiency (= quality of the various capabilities provided to the particular group), effectiveness (= degree of supporting this group for achieving its objectives) and users' future behavior respectively.

In Figure 1.(a) we can see the data users' value model, while in Figure 1.(b) we can see the data providers' value model (value dimensions per level and connections among them). We remark that the data user's value model includes in its first efficiency level five value dimensions associated with ease of use and experience (an extension of the 'ease of use' proposed by the TAM), performance (based on the 'system quality' proposed by the IS success model of DeLone and McLean), data provision capabilities (based on the based on the 'information quality' proposed by the same model), data search and download capabilities and data analysis capabilities for users. The data providers' value model includes two of the above value dimensions, ease of use and experience and performance, and also two additional ones associated with data upload and data analysis capabilities for providers. Both models in their second effectiveness level include two value dimensions associated with use and objectives' accomplishment, while the third level includes one value dimension associated with future behaviour.

It should be noted that the value dimensions of the first efficiency level are independent variables, which are under the direct control of the PSI e-infrastructure developer, who can take direct actions for improving them if necessary. In contrast, the value dimensions of the other two levels (effectiveness and future behavior ones) are not under the direct control of the PSI e-infrastructure developer/operator, and are dependent on the first level ones.

The above dimensions of the value generated by a PSI e-Infrastructure were further elaborated, and for each of them a number of individual value measures were defined. Each of these value measures was then converted to a question to be included in questionnaires to be distributed to stakeholders. All these questions have the form of statements; the stakeholders who fill the questionnaire are asked to enter the extent of their agreement or disagreement with them, answering the question: "To which extend do you agree with the following statements?". A five point Likert scale is used to measure agreement or disagreement with (i.e. positive or negative response to) such a statement (1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree). In Table I we can see for each of the abovementioned value dimension its corresponding value measures/questions. In this Table we can also see for each value measure whether it concerns data users (denoted with 'U'), data providers (denoted with 'P') or both ('P+U'). Two questionnaires have been formulated, one for data users (including the sections 1, 2, 3, 4, 6, 8, 10 and 11 of Table I), and another one for data providers (including the sections 1, 3, 5, 7, 10 and 11 of Table I).

TABLE I. QUESTIONNAIRE (VALUE MEASURES-QUESTIONS PER VALUE DIMENSION)

	1. Ease of Use and Experience (P + U)
1.1	The platform provides a user friendly and easy to use environment.
1.2	It was easy to learn how to use the platform.
1.3	The web pages are structured, well-organized and clear
1.4	The web pages look attractive.
1.5	It is easy to perform the tasks I want in a small number of steps.
1.7	The platform allows me to work in my own language.
1.8	The platform supports user account creation in order to personalize views and information shown
1.9	The platform provides high quality of documentation and online help.
	2. Data Provision Capabilities (U)
2.1	The platform provides a large number of datasets
2.2	The platform provides useful to me datasets
2.3	The platform provides to me complete data with all required fields and detail
2.4	The platform provides accurate and reliable data on which I can rely for my studies and for drawing
2.5	There are datasets from many different thematic areas (economy, health, education, etc.)
2.6	There are datasets from many different countries
2.7	The platform provides sufficiently recent data
	3. Performance (P + U)
3.1	The platform is always up and available without any interruptions.
3.2	Services and pages are loaded quickly.
3.3	The response of the platform in all the tasks I perform is quick.
3.4	I did not realize any bugs while using the platform.
	4. Data Search and Download Capabilities (U)

4.1	The platform provides strong dataset search capabilities using different criteria.
4.2	The platform provides several different categorizations of the available datasets, which assists significantly in finding the datasets I need.
4.3	The platform enabled me to download datasets easily and efficiently.
4.4	The datasets are in appropriate file/data formats that I can easily use for covering my needs.
4.5	The datasets have also appropriate and sufficient metadata, which allowed me to understand these data and also how and for what purpose they were collected.
4.6	The platform provides strong API for searching and downloading datasets (data + metadata)
5. Data Upload Capabilities (P)	
5.1	The platform enabled me to upload datasets easily and efficiently.
5.2	The platform has a good metadata model applicable for all its datasets, which includes appropriate and sufficient metadata that provide to the users a full understanding of the data and also how and for what purpose they have been call.
5.3	The platform enabled me to prepare and add the metadata for the datasets I uploaded easily and efficiently.
5.4	The platform provides good capabilities for the automated creation of metadata.
5.5	The platform provides good capabilities for converting datasets' initial metadata in the metadata model of the platform easily and efficiently.
5.6	The platform provides strong API for uploading datasets (data + metadata)
6. Data Analysis Capabilities for Users (U)	
6.1	The platform provides me good capabilities for visualization of datasets.
6.2	The platform provides me good capabilities for processing the datasets
6.3	The platform provides good capabilities for giving feedback on the datasets I download, e.g. for rating datasets, for entering textual comments on them.
6.4	The platform provides good capabilities for reading available feedback of other users of datasets I am interested in, e.g. ratings, comments.
6.5	The platform provides good capabilities for entering my needs for additional datasets
7. Data Analysis Capabilities for Providers (P)	
7.1	The platform provides good capabilities for data enrichment (i.e. adding new elements - fields)
7.2	The platform provides good capabilities for data cleansing (i.e. detecting and correcting ubiquities in a dataset)
7.3	The platform provides good capabilities for linking datasets.
7.4	The platform provides me good capabilities for visualization of datasets before uploading.
7.5	The platform allows me to collect user ratings and comments on the datasets I publish.
7.6	The platform allows me to collect users' needs for further datasets provision
8. Users Objectives Accomplishment (U)	
8.1	I think that using this platform enables me to do better research/inquiry and accomplish it more quickly
8.2	This platform allows me to draw interesting conclusions on past government activity
8.3	This platform enables me to create successful added-value electronic services
8.4	I am in general highly satisfied with this platform
9. Providers Objectives' Accomplishment (P)	
9.1	The platform enables me to open and widely publish datasets I possess with low effort and cost.
9.2	I am in general highly satisfied with this platform.
10. Use (P + U)	
10.1	I have spent a lot of time on the platform.
11. Future Behaviour (P + U)	
11.1	I would like to use this platform again.
11.2	I will recommend this platform colleagues.

IV. VALUE MODEL ESTIMATION ALGORITHM

The evaluation data to be collected will undergo extensive processing, in order to extract useful value-related knowledge from them. In particular, for each stakeholder's group the data to collected using the corresponding questionnaire will be processed using the following algorithm, in order to estimate the corresponding value model and identify improvement priorities:

1. For each value dimension a composite variable is calculated as the average of its individual measure variables.
2. Average ratings are calculated for all value dimensions (using the composite variables calculated in step 1); this provides a first class of 'analytics', which allows us to identify 'strengths' and 'weaknesses' of the PSI infrastructure.
3. For each value dimension of the first level we calculate its correlations with all value dimensions of the second and the

third levels (using again the composite variables calculated in step 1). In this way a second class of business analytics is calculated, which constitute objective indicators of the importance of first level value dimensions (which are ‘independent variables’ under the direct control of the PSI e-infrastructure developer/operator as mentioned in the previous section), as they quantify their impact on higher level value generation.

4. By combining the two classes of analytics calculated in steps 2 and 3 we can construct a high-level value model of the PSI e-Infrastructure, which visualizes the types of value generated by it for the particular stakeholders’ group and the relations among them, and enables a better understanding of its value generation mechanism.

5. Finally the value dimensions of the first layer, which are the only ‘independent variables’ within the control of the PSI e-infrastructure developer/operator, are classified, based on their average ratings they receive from the particular stakeholders’ group and their impacts on the value dimensions of the second and the third level, into four groups: low rating – high impact, low rating – low impact, high rating – high impact and high rating – low impact. The highest priority should be assigned to the improvement of the value dimensions of the first group, which receive low ratings and at the same time have a high impact on the generation of higher level value, so it is on them that we should focus our scarce human and financial resources.

6. Finally we repeat stages 2, 3, 4 and 5, but this time for the individual value measures/variables instead of the value dimensions’ composite variables.

V. Conclusions and Further Steps

This paper has presented a methodology for evaluating an emerging class of IS: the PSI e-Infrastructures. These IS aim to support both government agencies for opening their data, in order to be used for scientific, commercial and political purposes, and also various groups of users interested in them (e.g. scientists for conducting research, active citizens and journalists for drawing conclusions on previous government activity). The proposed methodology assesses a wide range of types of value generated by PSI e-Infrastructures for these two stakeholders’ groups: data users and data providers. Also, it includes an algorithm for advanced processing of stakeholders’ evaluation data, which results in the estimation of value models for these two groups and the identification of improvement priorities. The proposed methodology is going to be used for evaluating the PSI e-Infrastructure to be developed as part of the abovementioned ENGAGE project. This will allow improvements of the methodology, and also enrichment with qualitative parts (based on in depth discussions in small groups of data users and providers).

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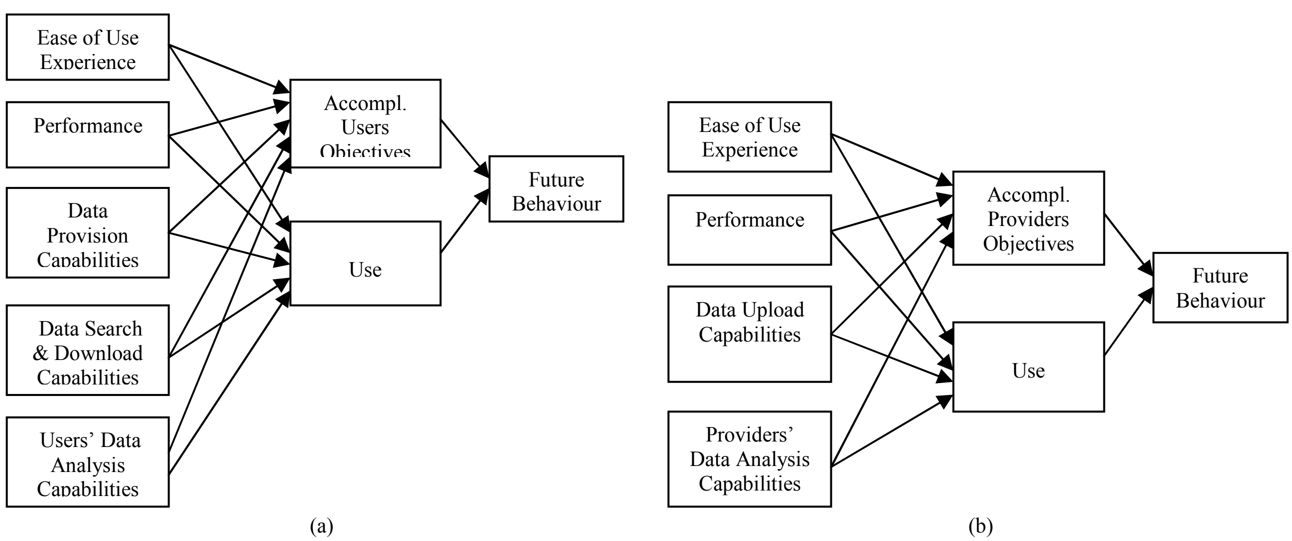

Figure 1. Value Models for (a) Data Users and (b) Data Providers