Introducing Integrated Acceptance and Sustainability Assessment of Technologies: a Model based on System Dynamics Simulation

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Abstract. This article introduces the cornerstones of Integrated Acceptance and Sustainability Assessment Model used for new and existing technologies evaluation. It combines the user acceptance metrics used by UTAUT model with additional socio-technical factors influencing development and running of technology. The model is developed using system dynamics approach and consists of four main flows – management, quality of technology, technology acceptance and domain development.

Keywords: Acceptance and sustainability, Integrated Acceptance and Sustainability Assessment Model (IASAM); System dynamics simulation, STELLA, CHOReOS

1 Introduction

Recent studies focus on behavioral aspects of technology acceptance or adoption. There have been plenty of researches on different factors that influence information technology acceptance – individual, organizational aspects, cultural, gender and professional differences. The most prominent model to be mentioned is Technology Acceptance Model (TAM)[1]. It has been criticized for focusing on initial adoption and not on continuous use [2]. There are also other approaches, for example Expectation-Confirmation Theory (ECT) [3] that initially originated in marketing sphere and Unified Theory of Acceptance and Use of Technology (UTAUT) that tries to consolidate eight approaches into [4].

The above mentioned adoption/acceptance theories focus mainly on exploitation stage and deal with prediction and modeling of the behavior of users that make the decision to adopt the technology or reject it. But to invest for elaboration of new technologies, one has to be sure that the possibility of failures has been diminished also in the development stage or during testing and maintenance, as different socio-technical factors influencing these stages might also lead to failure of the whole project. Therefore this article introduces the Integrated Acceptance and Sustainability Assessment Model (IASAM) and addresses the question, how to evaluate technology acceptance and sustainability at any chosen point of time of the technology life cycle and forecast the chances of technology to attract users and achieve the aims of its developers? What are the main elements and factors that influence the acceptance and sustainability of technology? IASAM suggests integrating the UTAUT approach for acceptance evaluation with other socio-technical factors thus framing united multi-level framework for technology assessment (see Fig. 1).

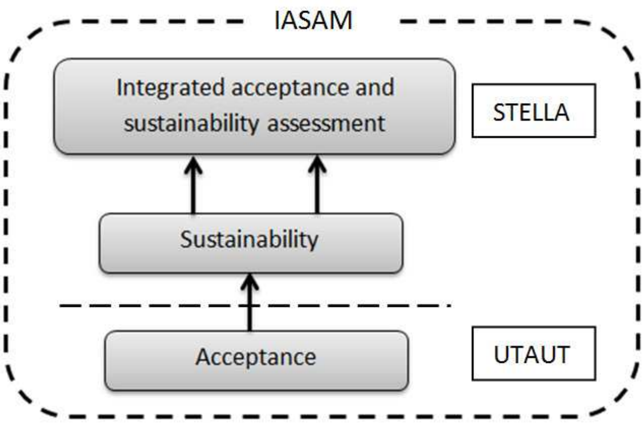

Fig. 1. Technology acceptance and sustainability assessment framework.

By introducing IASAM, the authors also propose the concept of technology sustainability for evaluation of the set of socio-technical factors that let the technology to be developed, implemented, maintained properly (according to the needs of all stakeholders) and attract long-term users and create positive output and/or outcome according to the purpose of the technology and initial intentions of its developers (financial, social, etc).

At this phase of the research the authors concentrate on Information, Communication Technologies and Electronics (ICTE) systems, but it is possible to broaden this issue by including different kinds of technologies and other products.

2 Previous Studies

There are several theories that partly reflect the issues of this research, but none of them gives full understanding about the factors influencing acceptance and sustainability combined. Moreover, only a few theories analyze system sustainability, although this parameter is critically important for decisions about investments in technology development and exploitation.

This article already mentioned several theories that question the factors behind the intentions and behaviors of users from psychological perspective. Different variations of TAM, UTAUT model, ECT are just some to mention in the discussion of technology acceptance and adoption research.

Technology life-cycle approach concentrates on defining universal stages that can be applied to technology and innovation research. In comparison with acceptance research, this approach focuses rather on market forces, management decisions. In the literature, it is common to see the terms industry life cycle, product life cycle and technology life cycle used interchangeably, ambiguously and often inappropriately. Moreover the discourse is dominated by the product life cycle while the technology life cycle has largely been neglected [5]. The unit analysis for technology life cycle is broader that a specific product or a process innovation, which applies to products sold in different markets [6]. Taylor&Taylor [5] point out that this is only the tip of the iceberg since there are also disconnects and inconsistencies pertaining to the various perspectives on the technology life cycle.

This approach does not answer the questions mentioned above as it concentrates rather on commercial/managerial problems and views technology as separate item and does not analyze the differences of the technologies themselves.

3 Technology Sustainability Explained

Generally speaking, sustainability is the capacity to endure. But it differs from viability, as it includes additional meaning. The terms "sustainable" and "sustainability" have recently gained wide popularity in different domains of life. Being one of the most discussed topics these terms have also gained many meanings and conceptual interpretations. Different definitions range over such concepts as resource use, long-term existence, responsible management, in different application situations they have environmental, economic and social dimensions.

The sustainability of technology is mostly analyzed within the context of environmental issues that the technology itself creates or problems it helps to tackle [7, 8]. Speaking about sustainable technology, one refers to environmentally, socially and economically responsible technology that eases promotes or creates some kind of benefits. Only a few authors broaden the understanding of sustainability of technology and especially ICTE (for example, Gubrod &Wiele write about sustainable software [9]).

In the domain of information system research, sustainability has been addressed in the research of digital sustainability [10], sustainable competitive advantage from IT usage [11] and software sustainability.

The authors define a framework for technology acceptance and sustainability – four basic flows of the model are described in more detail including the factors that impact acceptance and sustainability.

4 Technology Acceptance and Sustainability

Within this approach, there are four main flows that shape ICTE sustainability.

$$S = < M, Q, A, D > . \quad (1)$$

S – Sustainability;
M – Management;
Q – Quality of technology;

A – Acceptance;
D – Domain development.

Two internal flows are – Management of ICTE development and exploitation and Quality of technology. And two external flows are – Technology acceptance and Domain development. Each of them has several socio-technical factors that all together constitute the Integrated Acceptance and Sustainability Assessment Model. See Fig. 2 for interoperability of four flows and factors.

Continuing the previous studies on IASAM [12, 13] also here the authors use system dynamics approach for process specification and interactive simulation, which is becoming more and more popular in studying different sociotechnical systems, where engaging in a real system is not possible. In short, system dynamics modeling approach provides the opportunity to simulate a time-varying system with multiple feedback links and analyze quantitative and qualitative factors [12].

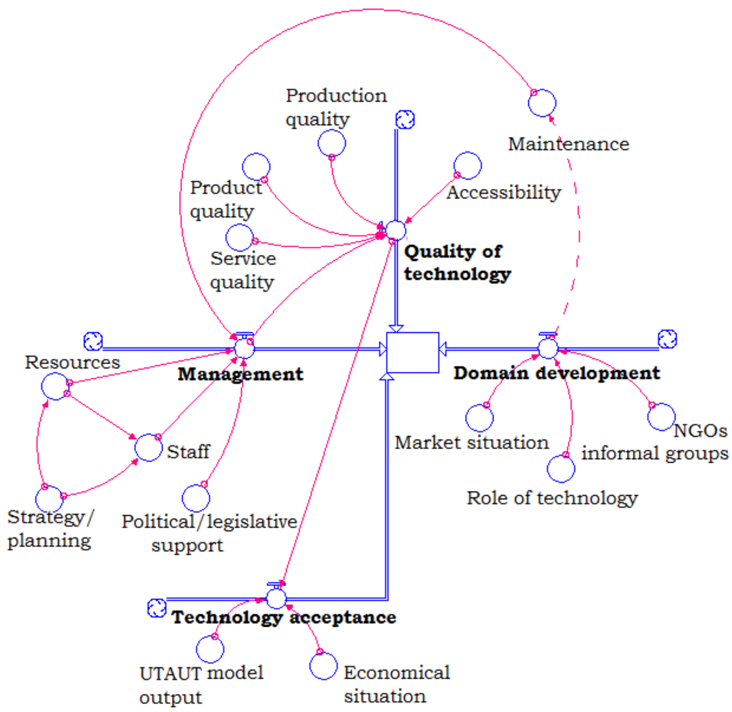

Fig.2. IASAM model in STELLA notation.

This approach allows describing technology development as a set of parallel processes. This set is characterized by:

- Socio-technical features of the system (dual nature: technical plus social and/or environmental factors;
- Development in a specific period of time;

- Involvement of multiple decision making entities, such as companies, institutions and individual consumers;
- Set of relevant internal and external socio-technical factors that impact the trends of individual change processes;
- Possibility to append or replace parameters [12].

Integrated technology sustainability and acceptance assessment model is created using the system dynamics simulation environment Stella [14].

The first of the four flows is the Management. This includes the management of technology development, as well as management of resources.

According to Gubrod&Wiele sustainability covers all aspects that potentially impact the use of any limited resource [19]. Therefore it is important whether and how the development of new technology is organized and managed. The main factors influencing the technology sustainability are as follows.

$$M = < R, S, Ps, L, Mt > . \quad (2)$$

M – Management;

R – Available resources, including financial and technical resources, etc.

S – Staff;

Ps – Strategic and managerial principles and approaches used to manage the resources ;

L – political/legislative support;

Mt – maintenance.

Technology acceptance and sustainability is also affected by its quality. Quality has multiple dimensions – technical quality, content and output quality, service quality. The approach in defining quality is similar to ICT success theory developed by DeLone and McLean in 1992 that was revised in 2003 [15]. They use a threefold understanding of quality – information quality, systems quality and service quality. As their model is aimed at information systems, the IASAM broadens the constructs.

$$Q = < M, P, Pr, Sv, As > . \quad (3)$$

Q – Quality of technology;

M – Management (flow described in section IV.A);

O – Product (output) quality;

Pr – Production quality;

S – Service (support) quality;

As – Accessibility.

The third IASAM flow turns to potential Technology acceptance by its users. Sustainability of technology cannot be explained without acceptance.

This flow is measured using basic constructs of UTAUT model. UTAUT is a definitive model that synthesizes what is known and provides a foundation to guide future research in this area. By encompassing the combined explanatory power of the individual models and key moderating influences, UTAUT advances cumulative theory while retaining a parsimonious structure [4].

Recent study on articles citing UTAUT revealed that current research on UTAUT constructs are impacted upon by many external variables across different studies [16]. That corresponds also to the strategy used in this article.

$$A = < U, E, Q > . \tag{3}$$

A – Acceptance;
U – UTAUT output;
E – Economical situation;
Q – Quality of technology.

The model also includes Domain development impacts. Despite the positive impact of technology development on the society overall, looking from the technology creators perspective at the same time, every innovation endangers its current position within the technology market. The main factors influencing this flow are as follows.

$$D = < Tm, G, R > . \tag{4}$$

D – Domain development;
Tm – Technology among other competitors in the market;
G – Nongovernmental activists/informal groups;
R – The role of technology.

5 Assessing the technology sustainability

The assessment according to the model is carried out using a set of criteria that were described in previous section. Each criterion is evaluated within a scale. This section reflects on the evaluation process and the scale.

The choice for a particular rating scale format can be broken down into two major components: the number of response categories to be offered, including the choice for an odd or even number of categories, and the labeling of response categories [17].

According to the developed IASAM model, each factor is measured with certain set of criteria. After examination of different types of scales and their characteristics, it has been chosen to use a 7 point Likert scale. Dawes concludes that either 5, 7 or 10-point scales are all comparable for analytical tools. Empirical studies have generally concurred that reliability and validity are improved by using five to seven-point scales rather than coarser ones (those with fewer scale points). But more finely graded scales do not improve reliability and validity further [18].

The result gained from evaluation of all criteria indicates the forecast of integrated technology sustainability and acceptance, measured as the % of expected maximum for the number of criteria that have been evaluated. The bigger the result, the more the technology satisfies the criteria of IASAM.

The methodology should be usable at any point of technology life cycle, so if there are questions that cannot be answered at the time of evaluation, then it should be marked with NA. The total number of questions marked with NA and expressed as percentage of total number of questions indicates the inner credibility of IASAM forecast. Accordingly, the smaller the percentage of inner credibility, the less credible is the forecast of technology sustainability and acceptance based on IASAM. Thus the model gives two numbers and they both characterize the evaluation of technology acceptance and sustainability.

6 Conclusion

Previous research focus separately on psychological or socio-economical aspects of technology acceptance, specifically on success of ICTE projects, on management systems, or diffusion on innovations on the whole. This paper presents a new approach for evaluation of technologies that combines socio-economical aspects and socio-technical characteristics of technology development and exploitation.

Technologies are changing rapidly and software is becoming larger and more complex. In addition, large-scale, distributed development poses new challenges [19]. The same is happening also with hardware and in the fields of Future Internet development and Cloud computing.

IASAM consists of four groups of factors that have an impact on integrated technology acceptance and sustainability – Management, Quality of technology, Acceptance and Domain development. Acceptance is measured using UTAUT methodology and other factors are evaluated using a set of pre-defined criteria. The model serves as a framework for successful technology development and assessment. By using system dynamics the model allows its users to monitor the variation of the IASAM index over time.

Approach practically has no limitations of application and it is intended to develop it to apply in other fields of economy. The validation of approach will be realised under the framework of other FP7 projects.

Acknowledgments. The IASAM model described above is under development and will be tested under the framework of FP7-ICT-2009-5 CHOReOS project No. 257178 (2010-2013) *"Large Scale Choreographies for the Future Internet (IP)"*to assess CHOReOS project pilots and whole project.

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