Systems Dynamics Use for Technologies Assessment

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ABSTRACT

Elaboration and introduction of a new technology is a complex and expensive task therefore it is necessary to assess the set of factors influencing the future of technology during the stages of technology emergence and development. The most important parameters of assessment are acceptance and sustainability of technology. Different models exist, but mostly they are static and do not offer possibilities for dynamic assessment in real time and do not forecast the sustainability of solution. In the framework of FP7-ICT-2009-5 CHOREOS project No. 257178 a new two step methodology, Integrated Acceptance and Sustainability Assessment Model (IASAM), of socio-technical assessment has been elaborated. This model will use system dynamic simulation in STELLA environment and will take into account technical, social and financial factors, and existence of concurrent technologies for sustainability assessment.

Keywords: technology assessment, system dynamics simulation, Integrated Acceptance and Sustainability Assessment Model (IASAM),

1. INTRODUCTION

Elaboration and introduction of new technologies is a worthwhile, but complex task. It is conceivable that new approaches, during and after valorisation, will impact upon existing technologies, and will change or replace them. But, at the same time, the feedback from providers and audience (social components) will have some pressure on the approaches and technologies elaborated in the framework of the new technology, and thus will possibly ask for changes to the approaches elaborated. Indeed, critical factors for the successful introduction of any technology do not only include quality of the technical solution, but also social and financial factors, which are integral attributes of the technology assessment, because almost any system is a socio-technical one. Static approach is most typical in technology acceptance assessment. Unfortunately such approach does not offer possibilities for forecasting of viability, continuity and sustainability of the new technology in real time. In the framework of FP7-ICT-2009-5 CHOREOS project No. 257178 the new methodology Integrated Acceptance and Sustainability Assessment Model (IASAM) of socio-technical assessment has been elaborated. The methodology will take into account current tendencies of technologies development and possible future trends. It will observe qualitative parameters such as existence of technologies, financial possibilities of stakeholders and marketing skills of promoters of the new technology, ergonomic of the new technology etc.

2. TECHNOLOGY

To create an adequate system which confirms to the set of predefined criteria and ensure its operation, the designer and further operational staff (S) must implement a series of tasks.

To meet these challenges different methods and techniques exist, which are usually specified and regulated (rules, manuals, guidelines, patents, algorithms, etc.) to ensure their repeatability.

The above may be termed as the logical structure (L). However, in order to facilitate the task diverse applications (software, hardware, transport and communication facilities, equipment, machinery, etc.) can be used. Those serve as an environment of the logical structure and form a physical structure (F).

This means that any technology $(Tech)$ in freely chosen moment of time can be described as:

$$Tech = \left\langle L, F, S, t_0 \right\rangle \quad (1)$$

where L – logical structure, F – physical structure, S – social factor, but t_0 – freely chosen moment of time.

We can discuss, whether to consider social factors (staff, users, and environment) as an integral part of the technology or not. These factors create additional complexity to the technology specification, and therefore are usually ignored. This is also one of the main reasons why the sustainability of technology is unpredictable.

A technology can be developed and applied, when appropriate skills and knowledge is possessed not only by the staff but also by the users. As well as technological, relevant social factors and circumstances exist too, and those determine the actuality of technology in use. Technology is not an unchangeable entity, because either it is changing, according to adopter's requirements, or no longer exists, that should be borne in mind when assessing any technology for sustainability and continuity.

In order to visualize the evolution of technology and its life cycle we can draw a parallel with the diagram of diffusion of innovation by Everett Rogers (Rodgers 1995) (see Figure 1).

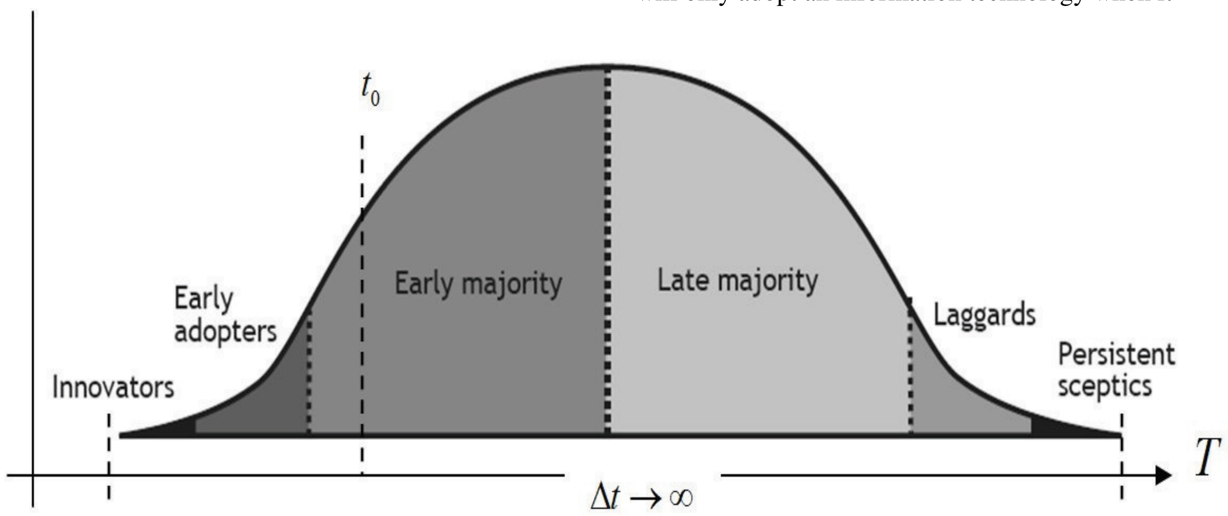

Figure 1: The Life Cycle of Technology

It shows that initially adopters are not many, but later their number is growing significantly. Once the technology has already won the public, more sceptical part of society joins, which calls for additional changes and improvements in the technology. Sooner or later the decline of the technology begins. Each developer's dream is to make a life cycle as long and profitable as possible, (to prolong the life cycle) i.e. $\Delta t \to \infty$, but not to be close to zero.

3. TECHNOLOGY ASSESSMENT

3.1. Technology Acceptance Model (TAM)

Different approaches, methods and models can be used for technology assessment. Technology Acceptance Model (TAM) (Venkatesh, Morris, Davis and Davis 2003; Lopez-Nicolas, Molina-Castillo and Bouwman 2008) was designed to predict IT acceptance and usage. It suggests that users formulate a positive attitude toward the technology when they perceive it to be useful and easy to use. TAM has been widely applied to various technologies, users and individual characteristics.

Studying virtual social networks Hossain and Silva (2009) proposed new theoretical construct that looks into the influence of social ties in an individual's acceptance process of a new technology

Pontiggia and Virili (2010) continued with the expectation that the candidate technology with a larger user network will be favoured in comparison to the one having smaller network, because users experience greater benefits with an increasing network size. Research shows that a larger user network size may push users to accept a system that could otherwise be discarded.

3.2. Task-Technology Fit (TTF)

Task-Technology Fit (TTF) model argues that a user will only adopt an information technology when it fits his/her tasks at hand and improves his/her performance. Goodhue and Thompson (1995) research identified eight factors that influence task-technology fit: data quality, locatability of data, authorization to access data, data compatibility between systems, training and ease of use, production timeliness, systems reliability, and IS developer relationship with users. Each factor is measured by interview using a seven point scale ranging from strongly disagree to strongly agree (Cane and McCarthy 2009).

Several studies (Yen, Wu, Cheng and Huang 2010) deal with integrated TAM and TTF models.

3.3. Unified theory of acceptance and usage of technology (UTAUT)

Venkatesh, Morris, Davis and Davis (2003) formulated a unified model (UTAUT) that integrates elements across the eight models – the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Planned Behaviour (TPB), the Combined TAM and TPB, the Model of PC Utilization (MPCU), the Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT). UTAUT had four core determinants of intention and usage (performance expectancy, effort expectancy, social influence, and facilitating conditions), and four moderators of key relationships (gender, age, experience, and voluntariness of use).

Zhou and Wang (2010) assessed mobile banking technology adoption using the task technology fit (TTF) model and the unified theory of acceptance and usage of technology (UTAUT). He found that performance expectancy, task technology fit, social influence, and facilitating conditions have significant effects on user adoption. The research considered task and technology characteristics, performance and effort expectancy, social influence and facilitating conditions used for mobile banking technology assessment. Unfortunately both models were still static and cannot be used for forecasting of sustainability of the new technology in real time.

3.4. Sustainable Assessment of Technology (SAT)

Even though modeling confirms technology acceptance by potential users, it does not verify sustainability of the technology..

The Sustainable Assessment of Technology (SAT) is a methodology elaborated by UNEP Division of Technology, Industry and Economics (DTIE) and International Environmental Technology Centre (Chandak 2007). SAT methodology integrates environmental, social and economic considerations. It focuses on environment and development together and puts them at the centre of the economic and political decision making process. SAT can be used for strategic planning and policy making, for assessing projects for funding, for assessment and comparison of alternative technologies and technology options. It is a quantitative procedure allowing sensitivity analyses and incorporation of different scenarios. SAT methodology determines three-tier assessment which incorporates screening, scoping and detailed assessment in conformity with customized criteria and indicators considering environmental, social and economic considerations. The results can be represented using star diagrams. SAT gives the possibilities for continuous improvement through Plan-Do-Check-Act (PDCA) cycle, but this process is not automatized.

Unfortunately SAT use for forecasting the situation development and changes of the technology raised by environmental, social and economic feedbacks and influence of other concurrent technologies in real time is problematic because the model is static. SAT methodology rather fits to the needs of governmental and supervision authorities aimed at analysis and planning at macro level, not at requirements of designers, promoters and adopters of new technologies.

Decision making in real time using the models mentioned above is problematic due to limited chance of getting an answer to the question "What happens if?" The existing approaches are static and mostly can be used for assessment of technology acceptance in the beginning of the life cycle. However, for real sustainability forecasting it is necessary to observe and take into account the influence of other concurrent technologies, feedbacks from social factors as well as influence the technology will create on existing technologies and how it will affect the function of designers and distributors network. To ensure convenient exploitation of the model in real time and manipulation with changing factors the system dynamics methods will be used.

4. INTEGRATED ACCEPTANCE AND SUSTAINABILITY ASSESSMENT MODEL (IASAM)

The Integrated Acceptance and Sustainability Assessment Model (IASAM) designed by Sociotechnical Systems Engineering institute at Vidzeme University of Applied Sciences consists of two phases (see Figure 2) and serves for assessment of technology acceptance and sustainability forecasting which is especially important in case of expensive and complex technology introduction.

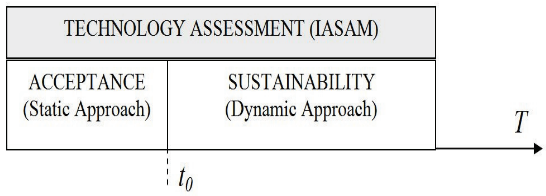

Figure 2: Technology assessment model IASAM

In acceptance phase the UTAUT model is used. Sustainability assessment structure involves a set of hierarchical models segmented in conformity with their functional role. The system dynamics simulation approach is used. The model is elaborated in STELLA environment (STELLA 2004) granting easy access to the model for the persons without specific knowledge in information technologies and mathematics. By simple graphical notation a set of differential equations are specified. Sustainability of technology (the stock in STELLA notation) is measured by the life time of the technology. At least four flows are described in the IASAM model at macro level. After that each flow and additional convertors can be specified more detailed at micro level. The main flows are Acceptance, Social impact, Finances and Expiration. The input flow Acceptance is determined by results of UTAUT and TTF use during first phase of assessment. However, Technology changes influenced by Concurrent technologies existence affect technology Acceptance (see Figure 3).

Also a feedback to Acceptance flow from Sustainability stock exists, because as long as the technology subsists in the market there are chances for its acceptance. The flow Finances characterizes possibilities the both most important actors: Stakeholders of the new technology and Adopters. If, for example, the Stakeholders have enough funding, they can affect promoters of Concurrent technologies. Prolonging the life cycle of technology increases the technology's influence on the finances of Stakeholders and Adopters. The flow Social impact take into accounts mainly governmental factors, for example, a support for different branches of industry, and Age or Epoch factor. Latter parameter characterizes the soul or the style of the age. Is provided technology in conformity with the style of the epoch? It is very subjective parameter maybe even sophistic, but no less important than other ones.

parameters further can be specified more detailed to develop accuracy of modeling results.

5. CONCLUSIONS

Before investing significant funds in the new technology development and introduction it would be advisable to ascertain if it will be accepted by potential adopters. Some more or less widespread approaches of acceptance assessment as TTF and UTAUT exist. However, the acceptance of technology is not enough to ensure that technology will be sustainable and during its life cycle will be able to earn back invested funding and gain the profit.

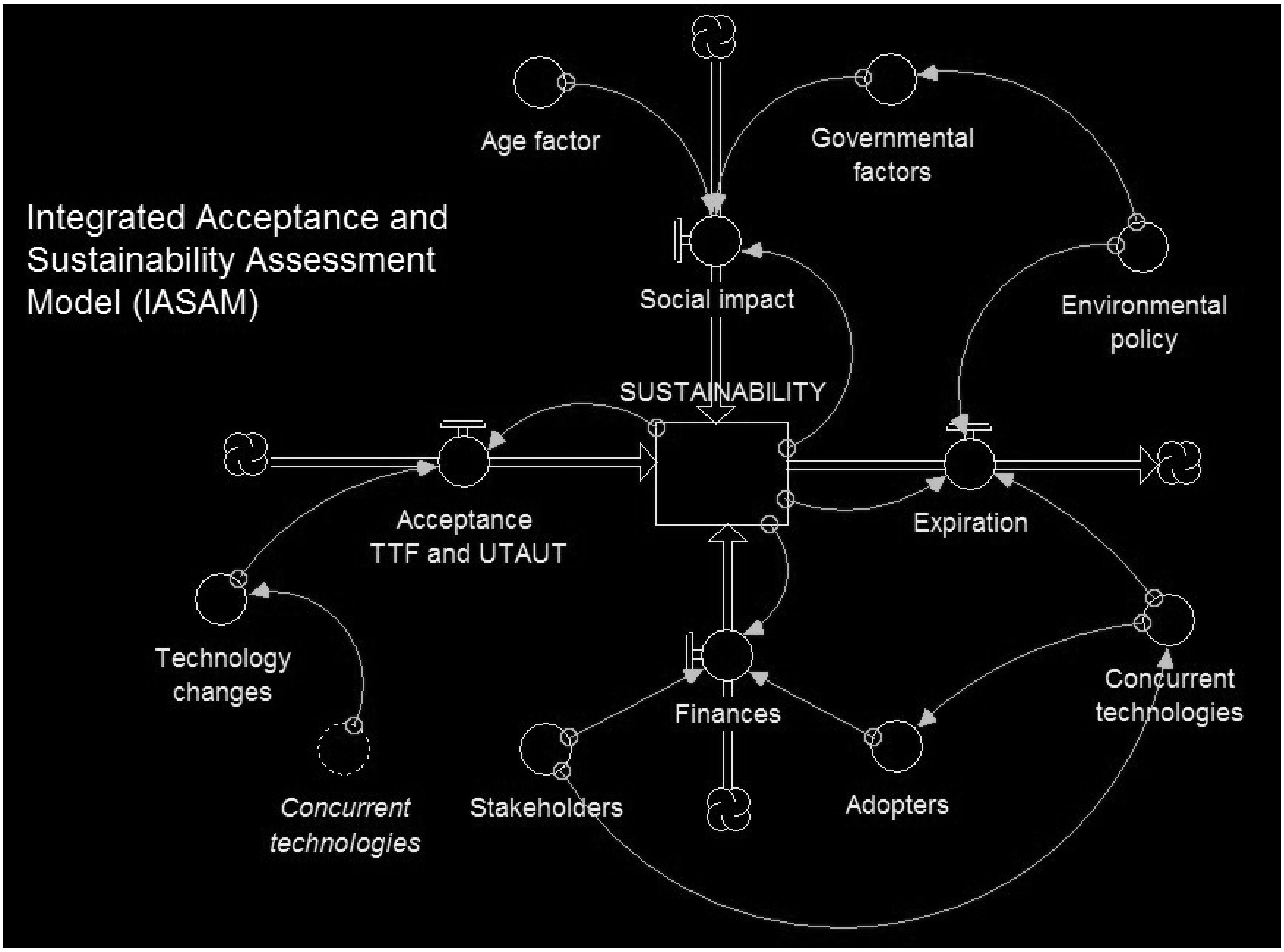

Figure 3: IASAM in STELLA notation

The Governmental factors can be affected by Environmental policy because it can be influenced not only by society but also by non-governmental sectors like Greenpeace, anti-globalization movements and other groups having different interests. The life cycle of technology is reduced by Expiration flow affected by Environmental policy and Concurrent technologies. The parameter Concurrent technologies can influence amount of Adopters.

The flows and the structure of the IASAM model are described above at macro level. Each flow and parameters further can be specified more detailed to develop accuracy of modeling results.

The current methods of sustainability assessment as SAT are more or less suitable for technology assessment by governmental authorities. Existing methods mainly are static and does not allow modeling and forecasting sustainability in real time.

Integrated Acceptance and Sustainability Assessment Model (IASAM) designed by Sociotechnical Systems Engineering institute at Vidzeme University of Applied Sciences allows assessing acceptance and forecasting sustainability of the new technology in any point of the life cycle. The systems dynamic simulation approach ensures operating in real time and access to assessment process by persons without special knowledge in mathematics and modeling.

It is expected that IASAM model will be developed and validated during next three years under the framework of FP7-ICT-2009-5 CHOREOS project No. 257178. The IASAM methodology will be used as general and adaptable tool for different technologies assessment.

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The IASAM model described above is under development and will be tested under the framework of FP7-ICT-2009-5 CHOREOS project No. 257178 to assess future Internet technologies elaborated.

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