SIMULATORS SUSTAINABILITY ASSESSMENT

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ABSTRACT

It is no secret that simulation plays an ever increasing role in solving various challenges outside the military domain.

Using simulation the policy planners can examine a variety of complex solutions before their implementation as well as forecast the impact of decisions on the attainable goal in general (Silva et al 2009).

Several simulators are being developed, however the lack of unified standards, task diversity and complexity raise costs for the development of a comprehensive simulator. These costs are significantly higher than in traditional software development.

This begs the question of sustainability regarding a new or already absorbed simulator as costs must be justified. How to determine technology sustainability? This question preoccupies users as well as investors.

It is still impossible to get a convincing answer. A few years ago the term "sustainability" was almost exclusively linked to environmental protection, and even today it is very rarely used in relation to technology sustainability.

More than five years ago the authors started developing the sustainability assessment methodology IASAM (Barkane et al 2010, Aizstrauta and Ginters 2013), which is based on system dynamics simulation. After several years of validation the work continues with the second version IASAM2, which left behind the Venkantesh UTAUT acceptance model in favour of Rodger's diffusion ideas.

Keywords: simulation, system dynamics, sustainability assessment

1. INTRODUCTION

The decision making support tools are typical sociotechnical systems reflecting the wishes of the decision maker and aligning these with the technical possibilities of the developer, thereby promoting project clearness and giving the beneficiary an opportunity to validate the offered solutions and to repair conceptual mistakes in the early stages of software design.

Designing policy decision-making tools consumes time and funding therefore it is reasonable to forecast the sustainability of the simulators thereby avoiding redundant investments in short-term solutions.

There are several theories that reflect the issues of technology and solution acceptance or sustainability research, but none of them give a full understanding of the combined factors influencing acceptance and sustainability. Theories such as Technology Acceptance Model (TAM) (Davis et al 1989), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh 2003), Expectation-Confirmation Theory (ECT) (Bhattacherjee 2001) focus mainly on the exploitation stage and deal with prediction and model the behaviour of users who make the decision to adopt the approach or reject it. These methodologies do not seem to fully answer the question how to evaluate technology acceptance and sustainability at any given point in time of the technology lifecycle and forecast the chances of technology to attract users and achieve the aims of its developers. And what are the main elements and factors that influence the acceptance and sustainability of technology?

The Integrated Acceptance and Sustainability Assessment Model (IASAM) (Aizstrauta and Ginters 2013) is a new approach for evaluating technologies that combines socio-economic aspects and socio-technical characteristics of technology development and exploitation thus framing a united multi-level framework for technology sustainability assessment based on system dynamics (SD) simulation.

2. INTEGRATED ACCEPTANCE AND SUSTAINABILITY ASSESSMENT MODEL (IASAM) STEP BY STEP

The new concept of technology sustainability was proposed to evaluate the set of factors that let the technology to be developed, implemented, maintained properly (i.e. according to the needs of all stakeholders), 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.) (Aizstrauta and Ginters 2013)

2.1. Methodology fundamentals

The IASAM approach is based on the opinion that technology acceptance research should not be separated from technological, economic and social evaluation. Although the term "socio-technical systems" is loosely used to describe many complex systems, five key aspects determine a socio-technical system:

- The system has interdependent parts;
- The system adapts to and pursues goals in external environments;
- The system has an internal environment comprising separate but interdependent technical and social subsystems;
- There is a choice in the system, e.g. system goals are achievable by more than one means;
- System performance depends on jointly optimizing the technical and social aspects of the system (Badham et al 2000).

According to the IASAM methodology there are four main groups of factors that influence technology sustainability S and thus comprise the backbone.

$$S = < M, Q, A, D \tag{1}$$

- Management (M) – successful management of every asset;
- Quality of technology (Q) – quality of the product (simulator);
- Technology acceptance (A) – acceptance of the new product (simulator) by customers/users;
- Domain development and societal processes (D) – the development of society demands more diverse technologies, which, in turn, after development, change society and also influence the demand for new technologies.

Thus IASAM consists of four flows in SD understanding that all together constitute what we call technology sustainability (see Figure 1).

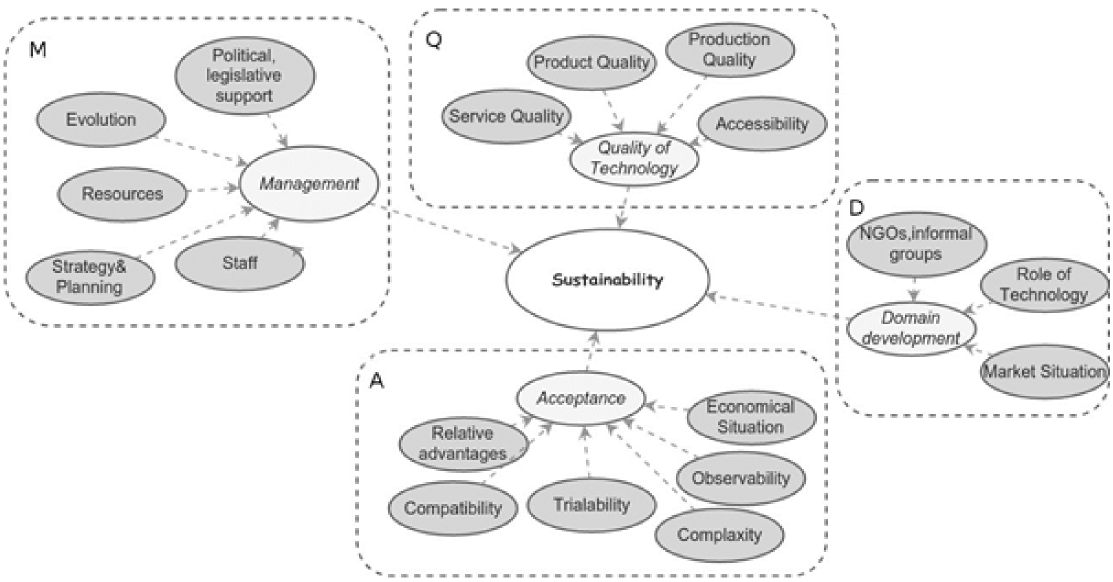

Figure 1: IASAM SD model in Insight Maker notation

Two internal flows are – Management of development and exploitation, and Quality of technology. And two external flows are – Technology acceptance and Domain development. Each includes several socio-technical factors that all together constitute the IASAM.

The IASAM approach can be viewed as the following sequence of processes that may be repeated over time based on the needs of evaluator (see Figure 2).

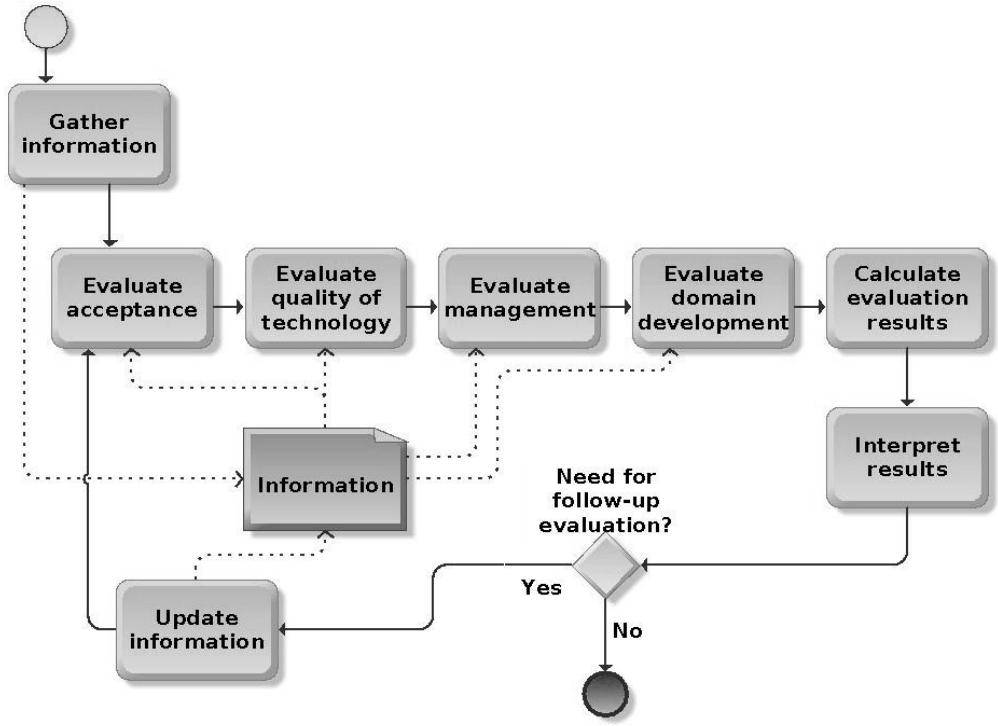

Figure 2: Assessment in conformity with IASAM rules

The evaluation of criteria is undeniably subjective, but it relies on the assumption that every evaluator, whether a technology developer or potential investor, will want to receive a reliable evaluation for decision-making. Each criterion is evaluated with the help of a specially formulated criteria description/statement. The respondent evaluates each description. The model follows these steps:

- The statement provided for each criterion is evaluated on the 7 point Likert scale. The questions are all formed in a unified manner – every statement is formulated in a positive way so that bigger score is always "better". If it is not possible to evaluate any criteria at the time of the current evaluation (for example, the evaluator does not know the answer because the technical specification is not yet ready), the criteria should be marked with "NA";
- The result gives a numerical value of integrated technology sustainability index (IASAM index) consistent with the assessment framework. It is calculated as the sum of all values from the questionnaire and divided by maximum possible value of questions answered:

$$IASAM\,2_{index} = \frac{\sum_{n=1}^{12} F_n + \sum_{i=1}^{49} B_i}{(N-C)*7}$$

where (F) – additional IASAM2 survey response values; (B) – initial IASAM2 survey response values, (N) – total number of questions; (C) – number of questions marked with "N/A". The final result is then interpreted according to IASAM2 methodology;

- The IASAM methodology was validated using Skype application sustainability research (Aizstrauta and Celmina et al 2013) and the IASAM index was measured in *skypes* making the assessment more understandable and perceivable. After validation it was also decided that IASAM needs certain amendments to make it more user-friendly without losing its multi-dimensional view.

The IASAM was tested under the framework of FP7-ICT-2009-5 CHOReOS project No. 257178 (2010-2013) *"Large Scale Choreographies for the Future Internet (IP)"* (CHOReOS, 2013) to assess project pilots.

2.2. Development and implementation technology management

Resources include available funds (or clear perspectives on this matter), time resources, equipment and knowledge in the organization (the technology development team). IASAM criteria help to evaluate the methods used to manage these resources. The detailed level of this and other Management flow factors and criteria used for evaluation can be seen in Table 1.

Table 1: Description of criteria “Resources”

	Criteria	Criteria description/statement
Resources	Available funds (existing or credit options)	Project management has a sound finance attraction and management strategy
	Time resources	Sufficient and reasonable time resources are planned for technology development and implementation processes
	Equipment	There is a sufficient amount of equipment or a sound plan for equipment procurement
	Knowledge in organization	Project management possesses knowledge creation, description, sharing, and other important knowledge management mechanisms

Each situation is of course different and no one can name one single project management approach that would fit all cases, but it is important that certain unified principles are applied in project management. The IASAM model being universal, evaluates only the core criteria.
The next factor is Human resources. ***Human resources*** have been separated from other resources on purpose as this is a very important resource in itself. Although people involved in the project can depend on other types of resources, it can play a crucial role in ensuring technology acceptance and sustainability. The evaluation criteria for this factor include knowledge and skills in technology elaboration and requirement engineering, knowledge and skills in technology distribution into the market, and motivation (see Table 2).

Table 2: Description of criteria “Human resources”

	Criteria	Criteria description
Human resources	Knowledge and experience in technology design and implementation	Involved staff has the necessary knowledge and skills or project management has defined a clear recruitment strategy
	Knowledge and experience in project management	Involved staff has the necessary knowledge and experience in project management or project management has defined a clear recruitment strategy
	Motivation	Project management has a sound and grounded motivational system for the staff

Strategic management principles include target setting, ex-ante analysis, risk assessment, market research, requirements engineering, etc. (see Table 3). Therefore the evaluation criteria are as follows – ex-ante market research, ex-ante competitor’s research, ex-ante target audience research, risk management, business plan, resource management, and project management. IASAM does not promote one specific project management approach, but it is important that the technology development team has the necessary skills and is familiar with project management tools and strategies.

Table 3: Description of criteria “Strategic management”

	Criteria	Criteria description
Strategic management	Ex-ante market research	Project management has comprehensive knowledge about the market situation in the established field
	Ex-ante competitors research	Project management has a clear notion and information about the activities of competitors as well as about competing technologies
	Ex-ante target group research	Project management has a clear notion of the target audience and its needs
	Risk assessment	Project management is aware of potential risks and possible activities to prevent them
	Resource planning	Project management uses adequate resource planning methods to ensure that the necessary resources are available in the right amount and at

		the right moment
	Project management	An adequate project management approach is chosen
	Business plan	There is a business plan (in the broadest sense)

To respect the influence from a governmental level, the model also adds the factor called ***Political/Legislative support***. This factor characterizes the public policy context for the given technology. It is important because development of technology very often means eclipse in traditional realms or demands serious re-orientation, so technology developers might need to face contra arguments by lobbyists. Also legislature can have a great effect on new technology. To mention the most extreme examples – the use of a technology can be prohibited or deemed compulsory. And this undeniably impacts the acceptance and usage of a technology. The evaluation criteria for this factor are – political support, lack of political constraints, ideology (technology conforms to dominant ideology, social norms, etc.) and legislature. The criteria and their descriptions can be seen in Table 4.

Table 4: Description of criteria “Politico-legal support”

	Criteria	Criteria description
Politico-legal support	Political level support	Technology development/implementation has political support
	Absence of political obstruction	The technology development/implementation process does not have any obstructions on the political level/lobbying against it.
	Ideology	The technology is not inconsistent with the dominant ideology/social norms and processes
	Legislation	Technology use is compulsory

Another factor left is ***Evolution*** that is also connected with the flow Domain development and ensures feedback to project management about the necessary amendments to ensure sustainability. This concept is rather close to the concept of maintainability. Maintainability can be defined as the ability of an item to be retained in or restored to a specified state. Maintainability has to be built into systems during design and development by realizing a maintenance concept. This built-in maintainability also means an ability to ensure changes in the provided technology as deemed necessary by situation changes in the domain environment. The evaluation criteria of this factor are – maintenance resources, evolvability of technology, feedback and maintenance processes (see the descriptions on Table 5).

Table 5: Description of criteria “Evolution”

	Criteria	Criteria description
Maintainability	Maintenance resources	Resources for maintenance are available
	Evolvability	The technology is able to evolve, its operation is not time-restricted
	Feedback	There are mechanisms to research feedback and make the necessary changes to the technology
	Maintenance processes	There are mechanisms to prevent/repair errors and flaws

2.3. Quality of technology

Product quality covers characteristics of technology outputs, the need for additional gadgets to use the output or compatibility with different platforms. The criteria for evaluation are as follows: output accuracy, output timing, output perceptibility, additional gadgets (needed or not), possibilities for technical integration. By output we mean anything that reaches the client/user and is used by him – information, services, sound, video etc. (see Table 6).

Table 6: Description of criteria “Product quality”

Product quality	Output accuracy	Output is consistent with the determined client needs
	Output perceptibility	Output is comprehensible and ready to use, no additional processing is needed
	Output timing	Output is ready when it is most convenient for the client
	Technical integration	The technology is compatible (or is customizable) with different platforms,

		formats.
	Additional gadgets/software	No additional gadgets/software are needed to use technology output

Production quality concerns the issues of the creation process – system design, coding practices and documentation management. Therefore the evaluation criteria include ICT architecture, Component and pattern re-use, algorithm complexity, coding practices, error and exception handling, system documentation as well as development process documentation (see Table 7).

Table 7: Description of criteria "Production quality"

Production quality	**ICT architecture**	**The architecture of the technology is sound and valid**
	Algorithm complexity	Algorithms are not unnecessarily complex
	Component and pattern re-use	The development of the technology involves component and pattern re-use
	Coding practices	Adequate coding methodology is chosen (waterfall, prototyping, spiral, etc.)
	Error and exception handling	An error and exception handling strategy is defined
	System documentation	The system (technology) is adequately documented
	Development process documentation	The system (technology) development process is adequately documented

Another crucial element for technology sustainability are the support services associated with the use of technology. ***Service quality*** looks at accessibility of support systems and the personnel working with support issues. This factor is measured using four criteria – support timing, support staff, support system (clients understand and accept it), the availability of support channels demanded by clients (see Table 8).

Table 8: Description of criteria "Service quality"

Service quality	**Support channels**	**Support availability conforms to the clients' needs**
	Support system	The support system is comprehensible and convenient for clients
	Support timing	Support is available when necessary
	Support staff	Support personnel is qualified or project management has defined a clear recruitment strategy

Besides the characteristics of quality, there is an additional factor – ***Accessibility***. With the help of this factor the model evaluates overall technological accessibility (physical accessibility as well as accessibility of necessary knowledge and skills). For example, to use Internet services and for them to become successful, the Internet should be easily accessible. There are three evaluation criteria – Infrastructure accessibility, ICT usage costs and ICT skills (see Table 9).

Table 9: Description of criteria "Accessibility"

Accessibility	**Infrastructure accessibility**	**The whole infrastructure necessary for technology usage is accessible to society (the target group)**
	ICT skills	Society (the target group) possesses sufficient ICT skills
	ICT usage costs	ICT is available to society in terms of financial capabilities

2.4. Technology acceptance and moving to IASAM2

In first version of IASAM the Unified Theory of Acceptance and Use of Technology (UTAUT) model was used to evaluate user acceptance. The UTAUT combines other models and includes four key determinants for acceptance analysis: performance expectancy, effort expectancy, social influence, facilitating conditions; and four moderators: gender, age, experience, voluntariness of use (Venkatesh et al 2003). The UTAUT survey was carried out separately and the results were used in two ways. First, a separate analysis of UTAUT survey results gave a comprehensive understanding of potential user acceptance. Secondly, the integration of certain answers into IASAM results added the acceptance perspective to the model.

The use of UTAUT involved a potential user survey and that created the greatest difficulty associated with IASAM evaluation. IASAM was planned to be a model that is applicable to any stage of technology development and it was very challenging to obtain surveys of potential users. Therefore it was decided to change the methodology for user acceptance evaluation and to replace UTAUT and potential user surveys with another approach. After a thorough research it was concluded that the user acceptance evaluation can be expanded based on diffusion of innovations by Rogers (Rogers 2003). It examines innovations from many perspectives. The extensive research includes an innovation-development process, an innovation-decision process, attributes of innovations and their rate of adoption, different adopter categories, as well as topics on leadership and change agents and innovation in organizations.
The main amendments of IASAM2 are related to the inclusion of theory of diffusion. Practically, the part of IASAM where UTAUT criteria were used has been replaced in IASAM2 by these five attributes of innovations:

- Relative advantage – the innovation is technically superior (in terms of cost, functionality, “image”, etc.) than the technology it supersedes;
- Compatibility – the innovation is compatible with existing values, skills, and work practices of potential adopters;
- Complexity – the innovation is relatively difficult to understand and use;
- Trialability – the innovation can be experimented with on a trial basis without undue effort and expense; it can be implemented incrementally and still provide a net positive benefit;
- Observability – the results and benefits of the innovation`s use can be easily observed and communicated to others (Rogers 2003).

Based on the work carried out by Rogers the criteria and sub-criteria were defined as follows (see Table 10).

Table 10: Description of criteria “Accessibility”

Relative advantage	**Economic profitability**	**Economic profitability is an advantage of using this technology**
Relative advantage	Low initial cost	Low initial cost is an advantage of using this technology
Relative advantage	Decrease in discomfort	Decrease of discomfort of some kind is an advantage of using this technology
Relative advantage	Social prestige	The use of this technology advances the social prestige of the user
Relative advantage	Saving time/effort	Saving time and/or effort is an advantage of using this technology
Relative advantage	Immediacy of the reward	The benefits of using technology are immediate and that is an advantage of using this technology
Compatibility	Social/cultural values and beliefs	The use of technology is positioned as compatible with social/cultural values and beliefs
Compatibility	Previously introduced ideas	The use of technology is positioned as compatible with previously introduced ideas
Compatibility	Client needs	The use of technology is positioned as compatible with client needs
Complexity	Complexity of technology	The technology is positioned and should be perceived by potential users as easy
Trialability	Trial availability	There are mechanisms (free downloads, trial versions, prototypes), that enable the users to easily try the technology
Observability	Observability of technology	The results and benefits of technology is easily visible by potential users

One additional factor included in evaluation is the Economic situation. It affects the development of new technologies as well as existing ones, depending on their type and aims. For example, during economic hardship, people may seek ways to economize and choose cheaper technologies instead of more expensive ones. This factor is described as the lack of outer economic constraints for technology use and distribution. One criterion is evaluated here and the description can be seen in Table 11.

Table 11: Description of criteria “Economic situation”

	Criteria	Criteria description

Economic situation	Economic situation	There are no external economic obstacles for technology usage and acceptance

2.5. Domain development

The model also includes Domain development as a set of factors that impact technology sustainability. Despite the positive impact of technology development on society overall, looking from the perspective of technology creators, every innovation endangers its current position within the technology market.

This section is a very important part of IASAM, as it adds contextual information about technology development, implementation and usage period. This also distinguishes IASAM from other acceptance and technology success measurement methodologies. These criteria reflect other market players as well as other stakeholders outside the market (see Table 12).

Table 12: Description of criteria "Market situation", "NGOs/informal groups" and "Role of technology"

	Criteria	Criteria description
Market situation	Similar products	There are similar technologies, this only adds new details.
	Uniqueness	The technology is unique
	Brand recognition	The technology uses (or is itself) a popular brand
NGOs/informal groups	Support	There are significant NGOs/informal groups or "opinion leaders" that (might) promote technology implementation, use and acceptance
	Lack of opposition	There are no significant NGOs/informal groups or "opinion leaders" that (might) hamper technology implementation, use and acceptance
Role of technology	Social role	The technology enables the transfer of some kind of popular idea into the electronic world
	Technical role	The technology enables the use of other technologies

Technologies among other competitors (***Market situation***) describe concurrent technologies as well as concurrent companies. It characterizes advantages among other technologies. There are three criteria to be evaluated – similar technologies, uniqueness and brand recognition (when technology uses a familiar brand).

The factor describing ***Nongovernmental organizations*** and activists or informal groups seek to represent different opinion-based groups that may influence the use of technology, by opposing it, or actively promoting its use. It is measured with two criteria – support and lack of opposition from such groups.

The ***Role of technology*** looks at the social (does it enable new ideas/paradigm shift?) and technological role (does it enable the users of other technologies?) of a technology. These criteria help to evaluate the necessity for the technology within the society at the certain point of its development. For example, a social role helps to determine whether and how the technology eases or promotes the implementation of new ideas, new social movements etc. To mention specific examples, massive open online course platform Coursera.org reflects and promotes the paradigm shift in education or stakeholders that empowers and enables a new level of public participation and local governance.

3. FROM IASAM TO IAAM2 – A SHIFT TO WIDER USABILITY

The substantial difference between IASAM and IASAM2 concerns acceptance evaluation and corresponding activities. An overview of the basic differences can be seen in Table 13.

Table 13: IASAM and IASAM2 differences

	IASAM	IASAM2
Acceptance evaluation	Potential user survey based on Unified Theory of Acceptance and Use of Technology (UTAUT) methodology (38 questions)	Five criteria (12 questions) based on attributes of innovations according to Innovation Diffusion theory
Sustainability evaluation	49 questions	49 questions

Data gathering methods	Self-assessment questionnaire + potential user survey	Self-assessment questionnaire
Data processing and analysis	2 phases – UTAUT survey analysis and then conjoint IASAM analysis	Integrated IASAM2 analysis
Result interpretation	UTAUT results are presented separately and within IASAM	IASAM2 results are presented in an integrated way

The newest IASAM2 version has several significant benefits:

- The assessment can be carried out by the interested party;
- There is no need for time and resource-consuming potential user survey;
- The model itself becomes more comprehensible, as the calculus, analysis and reporting can be done within one methodological framework;
- IASAM2 meets the initial goals of this tool – to be easy to use and universal in its applications (Aizstrauta, Ginters and Piera 2015).

4. IASAM USE FOR SIMULATOR SUSTAINABILITY ASSESSMENT

EC FP7 project FUPOL No. 287119 (2011-2015) „Future Policy Modelling" (Sonntagbauer and Ginters et al. 2012) given possibilities for different policy simulator design.

Under the framework of the FUPOL project we elaborated Zagreb Open Green Park Occupancy Analysis and Layout Design simulators, Skopje Vodno Mountain Recreational Activities Analysis tools, Skopje Inter-mobility Bicycle Routes Planning simulator and also the Yantai Economic Development Assessment tool.

IASAM2 was used for simulator sustainability assessment.

The Skopje Vodno mountain recreational activities occupancy simulator software allows definition of existing bike paths and docking stations and projects to improve the existing situation. The output is a calculation of the number of bikers using a certain resource and enabling a selection of a project that will offer the highest impact. IASAM2 index value was 0.79 and credibility value 0.91. That means that important issues regarding the management, quality of technology, acceptance and domain development are fully performed. The technology highly satisfies the defined model criteria and is expected to be accepted among target group members (local municipality decision makers and local society members willing to participate in decision design) and sustainable in terms of existence of technology and targets set within FUPOL project.

Skopje bicycles inter-modality simulator offers the City of Skopje and its citizens the opportunity to simulate the occupancy and usage of bike stations and bike parking lots. The overall goal is to increase the number of people that use bikes as a transport means, by taking several different measures, such as establishing bike inter-modality, initiating the development of parking lots, rent-a-bike facilities, new bike paths, improving existing bike paths. Skopje Bicycles received the highest IASAM2 index value – 0.88, (credibility 0.96). Important issues regarding all four flows of IASAM2 model – the management, quality of technology, acceptance and domain development – are fully performed or deliberated. The technology is expected to be accepted among target group members and sustainable in terms of existence of technology.

The Yantai urban economics assessment simulator offers the administration of Yantai the possibility to study the current situation of these industries in order to make decisions about a company's upgrade or closure in order to decrease resource consumption and impact on the environment. Yantai Urban Economics received IASAM2 index 0.78 (credibility – 0.95). On the whole the technology highly satisfies the defined model criteria. The lowest rating was given to criteria connected with feedback, evolvability and maintenance – these are the issues that might require further control. Nevertheless, the technology is expected to be accepted among target group members and sustainable.

Zagreb open green park occupancy analysis simulator provides the best solution for the facilities that would be included in the 2000m2 of green area situated near the Autism Centre. The simulation satisfied most of the potential user's demands and encourages interactions between autistic and non-autistic users, while avoiding possible conflicts between them. Zagreb-Open Green Park simulator had an IASAM2 index 0.80 and credibility 0.95. Also here the absolute majority of issues regarding the management, quality of technology, acceptance and domain development are fully performed or deliberated. The technology highly satisfies the defined model criteria. No criteria received an evaluation of less than five.

The high values of IASAM2 credibility indicate that the majority of questions have been evaluated and there are no issues that have not received careful deliberation. The results are not surprising taking into account the FUPOL project scale and clear management procedures.

5. CONCLUSIONS

The IASAM approach provides the opportunity to simulate a time-varying system with multiple feedback links and analyse quantitative and qualitative factors.

These application results lead to the following conclusions:

- Different factors of technology creation and distribution, and also contextual issues regarding, for example, the market and society have been taken into account in the development process of the simulators;
- According to the definition of technology sustainability these factors, when taken into consideration, allow the technology to be developed, implemented and maintained according to the needs of all stakeholders and attract long-term users;
- IASAM2 index values that are higher than 0.75 indicate that important issues regarding the management, quality of technology, acceptance and domain development are fully performed or deliberated. The technology highly satisfies the defined IASAM2 criteria and thus the evaluated technologies can be considered valuable from the acceptance and sustainability perspective;
- The model itself and the survey questions can be used as a checklist for further improvements and development planning.

Further activities of IASAM2 development will be related to methodology deployment of the Future Internet and providing SaaS access.

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