A SYSTEM DYNAMICS APPROACH FOR COMPLEX GOVERNMENT POLICIES DESIGN - APPLICATION IN ICT DIFFUSSION

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Abstract

In order to achieve e-governance, we are in need of new and more advanced tools, specifically designed towards supporting the policy making procedure. The purpose of this paper is to investigate the perspectives, provided by the development of decision support tools, to confront complex e-government phenomena. The analysis is performed using a System Dynamics simulation model that enables policy makers to investigate the estimated impact of planned government initiatives. Simulation applies on the diffusion of Internet and Communication Technology. The development of the model, made in collaboration with the Observatory for the Greek Information Society, addresses the digital divide in Greece. Data from the i2010 initiative indicators have been used for the simulation. The results, arising from the execution of alternative scenarios, indicate the parameters to be changed through the implementation of actions to have the best impact on society.

Keywords: *e-Inclusion, ICT diffusion, policy modelling, system dynamics, public policy making*

1 INTRODUCTION

Nowadays, more than ever, the need for improvements in public administration is evident. Whereas e-Governance is establishing as the most important public sector reform strategy, the potential of ICT in administrative processes should be exploited. For the transition to e-Governance is necessary to utilize the power ICT on public services to promote evidence-based, massively participative, justified and finally effective decision making.

On the other hand, the smooth operation of e-Governance functions presupposes a high level of e-Inclusion in the society, meaning the participation of all individuals in all aspects of information society, including dealing with public services. To foster e-Inclusion, EU has planned policies that aim at reducing gaps in ICT usage and promoting the use of ICT to overcome exclusion, and improve economic performance, employment opportunities, quality of life, social participation and cohesion. This perspective shifts the "public policy problem" of the digital divide from a matter of pure social inequality to a strategic issue in a global race for competitiveness [6]. In such complex phenomena, national and regional governments might have to deal with unprecedented challenges requiring a profound rethinking of the policy and strategic approaches to be implemented. Thus, the e-Inclusion issue calls for a deep understanding of the problem dynamics and dimensions, necessary to identify timely policy responses and to minimize errors.

In order to face the aforementioned problem and other similar phenomena, elected representatives and politicians should be empowered with ICT tools that will enhance the policy formulation process. For example, decision support tools allowing testing different policies and forecasting their impact, may provide significant policy assistance to identify efficient policy actions. These tools offer a dynamic assessment of policies that can result in more informed political choices and can be achieved through modelling approaches [21].

However, in order to confront complex government issues the limits of traditional analytical models should be overcame. In this direction, special interest has arisen in the domain known as Policy Modelling. A state of the art review of existing modelling and simulation approaches [3] has indicated the potential of their application in societal problems depending on their characteristics. From the aforementioned investigation of the above approaches it was concluded that System Dynamics and

Agent Based Modelling are the most promising to represent complex social phenomena under the policy making perspective.

Herein, System Dynamics was chosen to demonstrate that models can change the way policy making is done. The main purpose of the study is therefore to investigate how and to what extent external factors can influence the ICT diffusion process, seeking to acquire knowledge about the society and citizens behavior. The ICT diffusion process is analyzed herein by means of a System Dynamics simulation model. Several scenarios are applied, representing alternative policy actions in order their impact to be forecasted. The development of the model is part of the preliminary work conducted in the context of the PADGETS, a research project in the domain of "ICT for Governance and Policy modelling", supported by the Seventh Framework Programme of the European Commission.

This paper is structured as follows; initially a literature review on previous studies regarding the system dynamics method implementation is proposed. Section 3 presents the system dynamics model that was developed, scope of the model, assumptions and limitations and the linkages between each factor are described. Section 4 provides details about and the scenarios implemented for each policy (simulation parameters) and simulation results. Discussion on the results follows in section 5. Finally, the last section examines the perspectives for further research and the conclusions that are dawn are discussed.

2 SYSTEM DYNAMICS IN RELATED STUDIES

To investigate the current state of the art (in terms of practice and research) in the domain of system dynamics policy modeling, a study about the social simulation models particularly in matters relating to public administration was conducted. This section aims to provide an overview of indicative good practices that have already been implemented in the public sector and address specific needs associated with each research area in an innovative way. The literature review identified many examples of the System Dynamics methodology dealing with social phenomena [13].

The first model ever built, Urban Dynamics [7] remains a classic example of system dynamics successfully applied to an important public policy problem. The latter emulates the evolution of an imaginary city beginning from its growth, stagnation, and then decay. At the core of Urban Dynamics are the interactions between housing, business, and population sectors of an urban system. In addition to generating insight into the causes of urban decay, the urban model can also help policymakers design policies to improve decaying cities or prevent stagnation and decay in urban areas that are still growing.

But there are many contemporary examples of System Dynamics modeling tools as decision support from government agencies in various countries in the world as well. As technology is the main source of national growth a strategic choice was proposed in Turkey entitled as "National Science & Technology Policy" in order to enhance her ability in science and technology, and to get the capability of transforming them to economic and social benefit. To this direction a system dynamics model was constructed for policy analysis with respect to technology improvement as a tool to determine the various technology improvement policies [5]. The purpose of modeling was to understand technology improvement system, to identify the related entities with their effects on national technology improvement policy and to see the trend of the technology improvement in Turkey with respect to 15 years time. Through simulating some possible scenarios, decision makers could understand why some behavior pattern of the technology improvement policy system is occurring and to see what might be done to alter the pattern. System Dynamics appeared to be a potential tool for this field, although it contains a number of interactive and conflicting variables and parameters.

System dynamics methodology has been used in United States to capture the influence of tax policy on market competition between traditional telephone market and VOIP market [14]. Since, Voice Over Internet Protocol (VOIP) constituted the fastest-growing market in the United States providing telephone-like service without the restrictions of telecommunication regulations, state governments feared the implications on the heavily-taxed fixed line phone service, that was less tax revenue to support crucial public services. To help policy makers decide how to impose tax on VOIP services and reduce the impact of VOIP development, a system dynamics model was built to gain insight into interactions between the VOIP market, traditional phone market, and tax policy. The target audience of the model, mainly government officers involved in the development of telecommunications regulations and taxation policy, used it to test various policy settings to determine to what extent they

should tax the new technologies to collect maximum tax revenue with less impact on the market. Through the tax policy tests made, it was concluded that tax policy has little influence on market competition, traditional phone markets will continue to decline no matter what the tax policy is and finally, a fixed fee for tax can ensure stable tax revenue.

System dynamics modeling has been applied to issues of population health since the 1970s. One such case was detected in the United States, concerning chronic disease prevention [11]. A relatively simple model was built, exploring how a hypothetical chronic disease population may be affected by 2 types of prevention: upstream prevention of disease onset, and downstream prevention of disease complications. The model was not intended for actual policy making but for exploration of the methodology as a means of modeling multiple interacting diseases and risks, the interaction of delivery systems and diseased populations, and matters of national and state policy. Within three different policy scenarios tested, the conclusion drawn was that often prevention of occurrence can be neglected by the prevention of complications resulting in utilizing ineffectively available resources

Another implementation of the method in taxation policy, which combines the approach to public health, is related with the tobacco industry in New Zealand [16]. The study, carried out under the cooperation of the New Zealand Customs Service (NZCS) and Ministry of Health (MOH), analyzed the relationship of Customs Service outputs to desired government outcomes, in relation to the collection of tobacco excise duties and cigarette smoking. The study was done to demonstrate the utility of system dynamics in answering some questions of a common type in the public sector during policy development and review. Policy experiments with the model examined the effects of changes in excise duties and the effects of a price change on tobacco related behaviors and provided some very useful insights into the customs and health-related activities associated with the supply and consumption of tobacco products in New Zealand.

The paper digitization problem preoccupied the Italian Public Administration during the transition to an all-digital society. The need to cut down the production of paper through the digitization process, in fact, implies a deep change in many aspects that surround the world of documents, from the techniques and instruments needed to accomplish all the activities, to the definition of roles and competences in the documents' management context. To tackle these aspects, a System Dynamics analysis study has been conducted with the support of the Italian National Centre for the Information Technologies into Public Administrations (CNIPA) in order to show how social and psychological factors may in the end determine policy resistance and great obstacles to organizational change [2]. The model showed to what extent a "complete" digitization process would be positive and profitable for the administrations and in which ways the digitization process would spread. The finding that needs to be noticed is that such a great and demanding change would have enormous positive effects on the public administration's activities in terms of efficiency. System Dynamics predicted that the consequences of digitization will be perceived over time and will be relevant to cost savings and time, but in much less environmental impact.

Dynamic simulation approach was also used in a research project originated within the 'Swiss Priority Programme Environment' (SPPE) of the Swiss National Science Foundation (SNSF) focused on ecological issues [17][19]. In this study, a model simulating the management of solid waste at the local level, exemplified the dynamic interaction between public policies and environmentally relevant behavior of citizens. The objective was to identify solutions for environmental management. Therefore, System Dynamics methodology was the core device for integrating concepts from different disciplines in a simulation model enabling the formulation of a dynamic theory in the context of environmental management and analysing issues of policy resistance and compliance.

The case study of modelling the situation of Iran cell phone market indicates that the methodology of System Dynamics could prevent an incorrect implemented government policy [22]. Towards the effort to decrease the dependency of the country from imported goods, government of Iran increased the rate of tariff of imported cell phones suddenly in 2005. This strategy had adverse effects on the development of the domestic mobile phone industry, a fact that could have been avoided if the model that was built later would have been used. After the execution of three alternative policy scenarios, it was concluded that the best decision for the government would have been to increase the tariff rate gradually in order to enable domestic manufacturers of mobile phones compete with their foreign rivals improving their quality at the same time.

Finally, the case of E-Mexico constitutes another recent implementation of System Dynamics methodology for an e-government project [15].This program is defined as the strategy to create web-based content to the citizen in the areas of education, health, economy and government. Using the same technological infrastructure and under the leadership of the same Federal Ministry, four different networks of government and nongovernment organizations engaged in the creation of Internet portals to create relevant content in these areas. In this case System Dynamics was used as an integrated and comprehensive approach to understand complex e-government phenomena. The model that has been, represents a theory of how institutional, organizational and technology elements interact among them to produce different technology enactments.

Additional examples of System Dynamics implementations have been identified on the field of occupational safety, the energy sector, national security (military organization), in the adoption of automation technologies, in changes in socio-political structure of a country and generally in all areas related to the development of a country.

3 THE ICT DIFFUSSION MODEL

For the implementation of the model, the environment of Vensim PLE [20] was selected due to its easiness of use. Vensim supports fully the methodology of System Dynamics, providing flexibility in designing graphs, contains numerous tools for analyzing and testing scenarios, and finally has the capability of direct visualisation of simulation results.

Problem Description and Dynamic Hypothesis

The model addresses the problem of the "Digital gap in Greece". Digital divide is a term coined to characterize the inequality in the relationship between groups of individuals and their relationship with formation communication technologies (ICTs). The application of the model can be considered as an attempt to foster a higher level of e-Inclusion and increase the diffusion of complementary activities such as eGovernment and eParticipation.

The model tries to conceptualise the multidimensional phenomenon of the ICT Diffusion on vulnerable social groups, monitoring the aspects of the concrete problem and the correlations between them. Thus, the model examines the factors that constitute the digital divide and captures quantitative data obtained from relative studies [4][9][10] with the view to predict what impact will result from implemented actions to them. Focusing on social groups at risk of digital exclusion, it models the process of their e-Inclusion, by simulating the evolution of any parameters of the issue.

To assess the digital divide an indicator system has been identified by the Greek Observatory [25] for IS that utilizes the annual surveys of the i2010 initiative conducted for households in Greece [23][24][24]. i2010 strategy is the EU general policy framework for the information society and media for the period 2005-2010 that provides the framework for eInclusion European action. The proposed model incorporates the indicators that are measured by the i2010 strategy concerning the following factors of digital divide [23]:

- Internet access and usage
- Availability of broadband infrastructure nationwide
- Internet literacy and digital skills

The affect on those indicators resulting by any policy actions are estimated by testing alternative policy scenarios. By altering one or more parameters of the model, the user is able to execute "what if" scenarios in order to compare different sets of policies and finally observe the overall impact on society.

The casual loop diagram of the model depicts all the system's parameters and the linkages between them. The arrows in the following schema illustrate the relationship between each of the factors involved in the behavior of the system. Plus sign symbolizes the positive effect of a variable to another and minus the negative one.

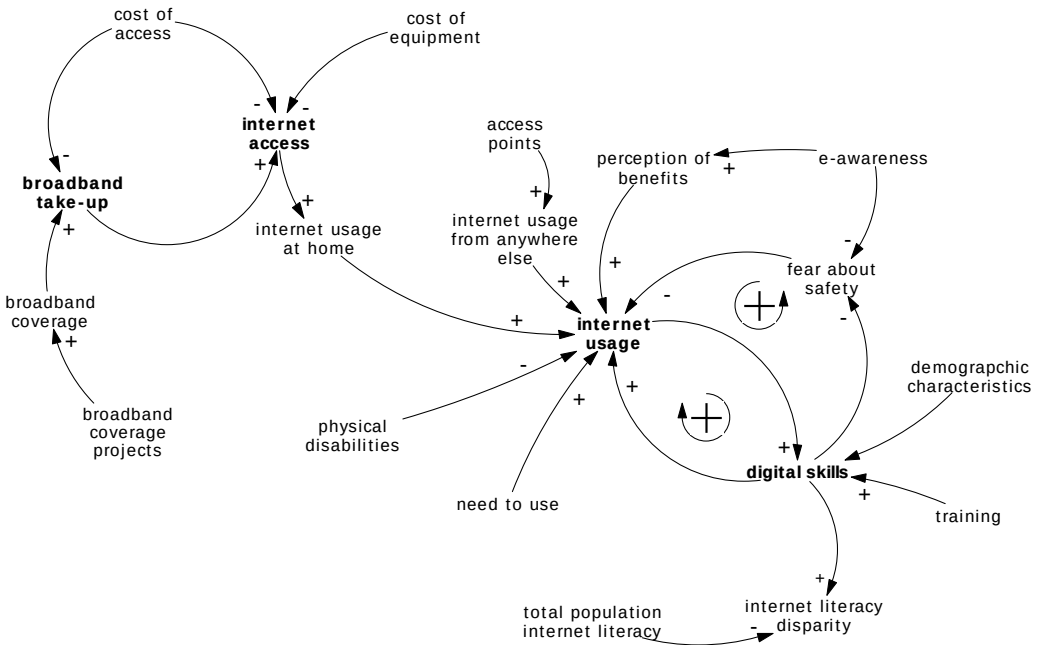


Figure 1. Casual loop diagram

The final structure of the model is presented with the following stock and flow diagram. Based on the previously presented casual loop diagram the stocks and flows, the basic building blocks of the System Dynamics methodology, were identified. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock. The rest variables are auxiliary and contribute to the calculation of the flow rates. For example, in our case the percentage of broadband users increases according to the broadband take up rate reducing in parallel the stock of internet potential users. Then, the flow of broadband take up rate is determined by the cost of broadband access, the technology factor and the rate of broadband coverage.

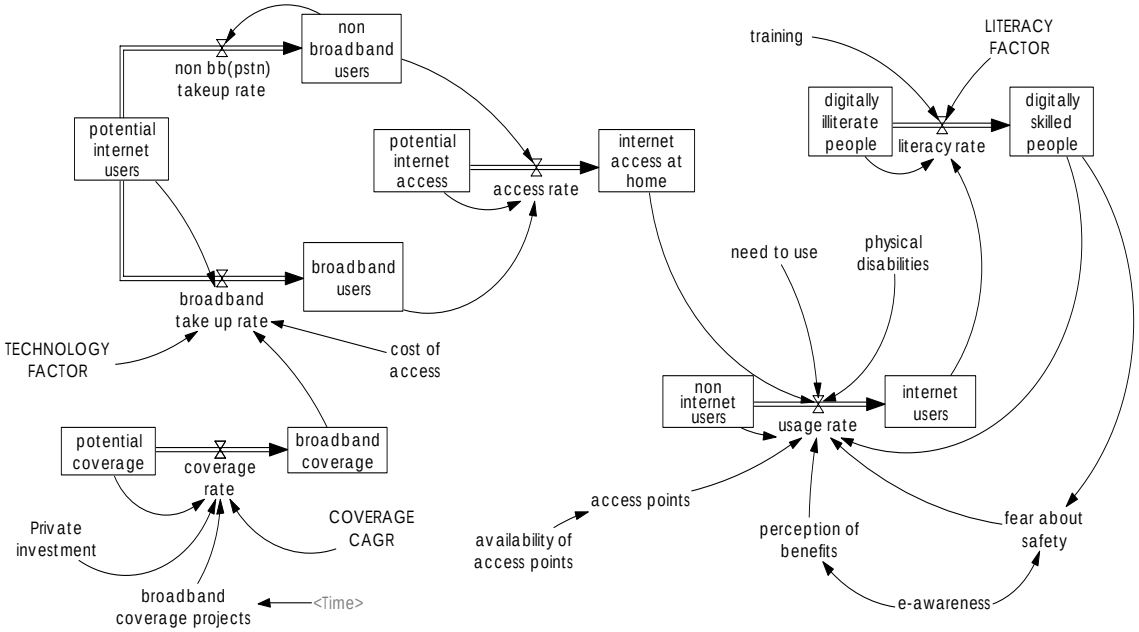


Figure 2. Stock and flow diagram for ICT diffusion

4 SIMULATION OF THE ICT DIFFUSION MODEL

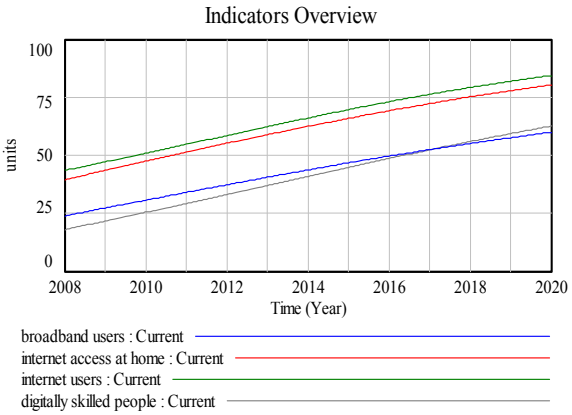
The model is designed with a time horizon of 15 years, from 2005 to 2020. Due to the rapid development of ICT and the ongoing actions towards the digital convergence, we consider the above time interval long enough to provide data on which we model the diffusion phenomenon. The data from 2005 to 2008, which are available through the measurements of indicators by the "Greek Observatory" should be enough to see historical behaviors in order to set the data constants and

formulate the equations between the variables. The model generates values of the model variables on an annual basis from 2008 to 2020, but can estimate values in shorter basis. The initial values of the indicators consist of the most recent measures available. All percentages reflect the proportion of each cluster in relation with the total population in Greece.

In order to examine the impact of possible policy actions on the indicators four output variables have been selected and are being observed during the whole simulation lifecycle: the number of broadband users, the volume of Internet access at home, the percentage of Internet users (either broadband or not) and finally the percentage of digitally skilled people. There were 5 scenarios implemented for the analysis of different policy actions to reinforce the ICT diffusion. The outputs of the runs were evaluated accordingly and compared with the output corresponding to the base run simulation. Scenarios applied to the simulation model are given below.

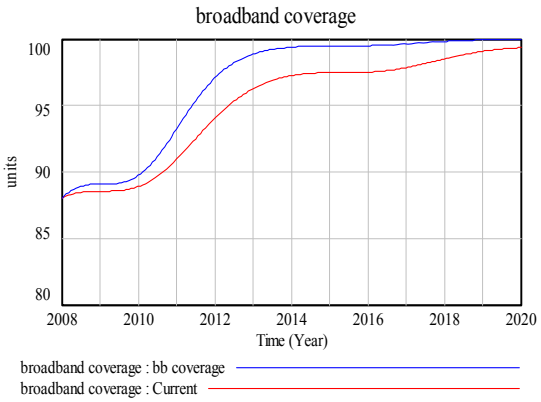
Base case run of the model

The model output for the selected variables for the base case run of the model is provided in Figure 3 and Table 2. The base case run is the output from the simulation run from 2008 to 2020 with the initial set of model assumptions. As illustrated, all four variables are characterized by an upward trend and reach very high levels at the end of the simulation. The percentage of digitally skilled population presents the greatest growth rate, reflecting the accumulation of the increases of the rest variables that are affecting it.



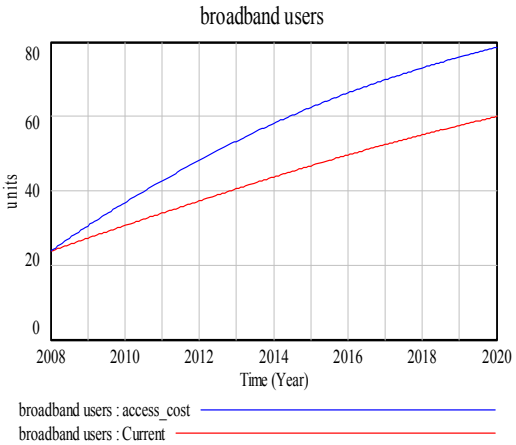
Scenario 1: Increase in broadband coverage rate

First scenario represents what will happen if government decided to intensify the broadband coverage projects. However we examine only the coverage rate, since the number of annual coverage projects depend on factors that are beyond the system boundaries. The figure concern only the variables that are affected in the specific plot and depict the policy result that is to achieve full broadband coverage in the country faster. As the broadband coverage is already high in Greece alternative actions should be considered to increase the number of broadband users.

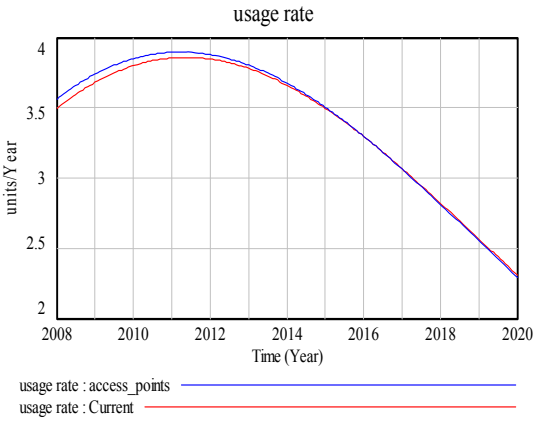


Scenario 2: Reduction of access cost

Simulation second scenario assumes that a policy that reduces the cost of Internet access is planned, for example a government subsidy for the monthly fee for broadband access services. Another example of such an action is the programme "Diodos" implemented by the "General Secretariat for Research and Technology" that foresees special rates to purchase a broadband connection for students. The implementation of such a strategy will lead to significant growth in broadband and overall Internet access, which is expected since the smaller the cost will be more people will gain access. A small part of this increase will be transferred in the use of Internet but the impact on digital literacy will be minimal.



Scenario 3: Increase of access points



A similar policy with the previous one could be to increase the available public access points. The specific policy already applied within projects involving municipalities and regions in Greece and will be probably amplified through the installation of free Wi-Fi access points in transportation stations, an action that is currently under discussion. The aforementioned policy actions could have been tested with the proposed simulation tool before being taken decisions. As shown in the figure, the usage growth rate could present an initial increase, but will be declined after 2012 due to the remaining potential internet users, reflecting the balancing loop of the model. However this increase is not projected in the overall internet users, due to the fact that the majority of the population is online mainly from home and make use of access points just supplementary.

Scenario 4: Notification about ICT benefits

Another candidate policy for the dissemination of ICT could be targeted to inform citizens about the benefits offered by ICT. For example, a campaign to make citizens aware of the opportunities and services provided by the Internet will increase the overall perceived usefulness. The current scenario's output showed that a movement like this would entail a slight increase in usage, some of which will shift and increase digital skills. However, the change caused is so small that such policy action would not have a significant impact.

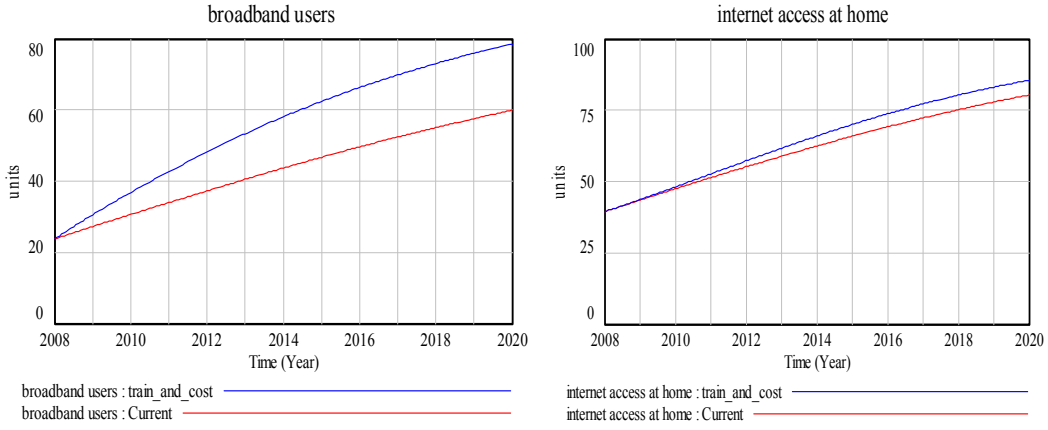
Scenario 5: Population training

The last scenario indicates the results would be expected by reinforcing citizens' digital skills. Educational training programs for various social groups can contribute to digital inclusion.

5 SIMULATION RESULTS

The most recent surveys of the Greek Observatory validate the model as the simulation results of previous years (2008-2011) coincide with the real metrics at a large extent. Specifically, in 2010 already 46% of Greek households have internet access which converges with the prediction of the base run concerning the household internet access which was at 47,45%..

Simulation results suggest that an approach that combines more than one policy may be more effective, reflecting the reinforcing feedback that System Dynamics is based on. The above comparisons allowed us to understand that the most influencing factors are the cost of access and the population level of ICT skills, as the diffusion processes for the other scenarios did not show any significant difference. Therefore, an alternative scenario combining the second and the fifth policy choices could affect all the variables very significant as seen from the following charts. Figure 9 represents the output of simulations referred to the policies of access cost reduction and citizens training. As it can be observed, the percentage of digital literacy and the usage rate projected into the future reach very high levels in the last year of simulation.



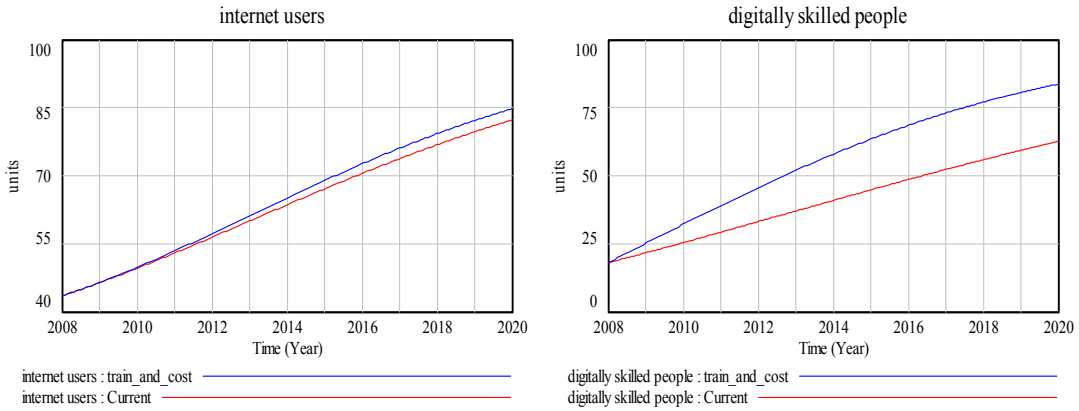


Figure 3.Output of the simulation approach combining scenario 2 and 5

The above plot that depicts a desired evolution in the diffusion process can provide precious information for policy makers, highlighting the concept that they should design and imply specific policies. Overall, the implementation of the model aims to prove that similar techniques such as other modelling approaches and policy simulation experiments can also be used, as a grounded decision support system that informs and enhance the debate on policy design.

6 CONCLUSIONS

Previously the process of ICT diffusion in Greek society has been projected in the future through a System Dynamics simulation. The results obtained show that the factors, which exert a significant influence on ICT diffusion are related with the digital literacy of people and the cost of Internet access. However the model is a "prototype" only and hence does not contain all the variables and relationships that would be necessary to answer the research questions in depth. Although, the model is regarded as sufficiently "robust" to provide indicative results to the policy questions it can be further developed to include additional parameters of the problem and can be used the basis for a more comprehensive policy tool that could be further developed either for Greek and or any other country trying to struggle with the implications of policy relating to the digital gap. In addition it can be customized in order to overcome the drawback of not accounting external factors for, e.g., the socio-economic context of each country.

However the current paper does not only intend to present the results of a simulation of a real policy problem, but also to demonstrate the value of System Dynamics methodology and other policy modeling approaches in better understanding of social phenomena and in visualising their internal processes. Under this perspective, a significant aspect in model building is the engagement of policy makers. Civil servants, governmental actors and other stakeholders should be strongly involved in the preparatory work needed to be done before creating the model. Finally, future work should be performed to build a network of peers from the public and private sector interested in policy modelling, visualisation, mass collaborative platforms, large-scale societal simulations and in the use of these advanced tools by governments.

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