A new system dynamics model for the analysis of the paper digitization process in the Italian Public Administration

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Abstract

This study deals with a System Dynamics analysis of the paper digitization problem during the transition to an all-digital society. The efforts are focused on the description of the situation in terms of the relationships between systemic variables that define the underlying structure of the problem. The referring context is the Italian Public Administration. The central spots of the analysis are the diffusion of the "new technology" and the problem of the archives' dimensions, which have been formalized, by means of the creation and the study of a casual loop diagram, into a dynamical hypothesis. The systemic approach that we used through the whole study, allowed us to consider many collateral aspects that are crucial in this issue, and provide a rich analysis that also shows how social and psychological factors may in the end determine policy resistance and great obstacles to organizational change.

1. Introduction

This study has been conducted with the support of the Italian National Centre for the Information Technologies into Public Administrations (CNIPA- Centro Nazionale dell'Informatica nella Pubbica Amministrazione - www.cnipa.gov.it) with regard to the problem of paper documents dematerialization, which does not only imply dematerializing paper archives but also allows the whole Italian Public Administration to switch to innovative processes and technologies in order to progressively abandon the old paper format for all kinds of communications (internal or external) as well as for the official documentation [1].

1.1 Current Normative Situation

From a juridical point of view, there are still two issues on which the debate is still open: the need of the Public Administrations to preserve documents integrity and their storage through time. As far as the first issue is concerned, the international normative scenery and, more specifically, the English and the American ones, is highly focused on it, with a particular attention to the protection of privacy as well as the prevention of fraud [5, 6, 7].

As far as the storage issue is concerned, the question as to whether it is possible to cut out the paper archives after turning the paper documents into digital ones is very delicate; in fact in Italy every single document of every archive is under the protection of the Ministry of Cultural Heritage and Activities, so that discarding documents is not such an easy and "automatic" task: towards this end, special commissions have been nominated, but they do not meet very often and what emerges from a preliminary analysis is that the existing paper will not be destroyed. It is therefore necessary to reduce the production of paper in a relatively short period of time. [22, 23]

1.2 The diffusion of the New Technology

In the study of the digitization of documents, particular attention should be paid to the reaction of the population to the substantial change of technology. One of the goals of this paper is to study and underline what the consequences of the introduction of the new technology would be from the user point of view. The starting point of the analysis has been the study and the applicability of the Bass Model, in order to describe the introduction and diffusion of new products on the market. It has been adapted to the digitization issue, but even in this case, like in the original model, we considered two main adoption drivers: advertising and word-of-mouth. The study was further enriched by including in the analysis a focus on possible emergence of phenomena like policy resistance and other typical aspects of a substantial change affecting the diffusion of the new technology.

1.3 Digital and Substitutive Documents Conservation

As far as the conservation of documents over time is concerned, there are two ways of archiving documents according to the Italian Public Administration laws, in dependence on their original native format. If the document is created directly in a digital format, its life cycle will be entirely digital, from the assignment to the conservation. On the other hand, a document that is firstly created in a paper format will undergo a process of digitization, that will initiate the so-called "substitutive conservation" process (which is therefore typical of those documents that are generated in a paper format, but are then converted in a digital one) [5, 6, 7].

In this paper we assumed that all the documents are generated in a paper format. This means that they will be archived in paper archives, since according to the Italian legislation no paper documents can be destroyed, unless they undergo a very long and complex discarding

process. Thus, in our model, we will have both paper archives (including all the produced paper documents) as well as digital archives (which will include only the part of paper documents which has been digitized).

1.4 Pros and cons of the digitization process

The ultimate adoption of the new technology would definitely imply some fundamental advantages like paper saving, costs and space saving, as far as the conservation is concerned, but also time saving for the document managing tasks, especially due to the much shorter time needed to find and trace documents from the archives and to send and receive them digitally.

On the other hand, though, there are some obstacles that have to be considered to give a realistic view of the problem. 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 redefinition of roles and competences in the documents' management context. All these aspects, together with the inevitable obsolescence of the technological supports (a document that today gets copied on an certain technological support - i.e. an optical one - could be not readable tomorrow on a new support), may thus lead to an increase in the above mentioned policy resistance behavior of the overall system.

2. Hypothesis, goals and sources for the dynamic analysis of the documents digitization process

The basic hypothesis that has been considered in the description of the model refers to the format of the documents: in order to conform to a realistic situation, we considered the simplified case in which only paper documents are generated. Once they get to the Administrations, either they are managed in a digital way or in the traditional one. This means that, in any case, they are introduced in paper archives and a variable percentage of them gets also digitalized and electronically archived.

The main goal of the model is to show to what extent a "complete" digitization process would be positive and profitable for the administrations and in which ways the digitization process would spread in the current context.

All the information needed to implement the model was provided by the Italian National Centre for the Information Technologies into Public Administrations (CNIPA). It was, however, necessary to recur to some hypothesized behavior or function for some of the systems variables, but such hypotheses have been validated, by domain experts, as totally realistic [1, 22, 23].

Our analysis also includes some of the elements that often are not considered in a model because they are believed to be not directly involved in the technical digitization process, but according to a systems thinking and dynamic approach, those variables are crucial in stating whether the system will have a certain behavior or not.

3. Causal loop diagram and feedback loops

A causal loop diagram is basically an oriented di-graph G(V,E), where the vertex set V represents "parts" (or variables) of the system, and the edges set E represents effects (positive

or negative) that a particular variable causes on the next linked one. A causal loop diagram describes the main cause-effect relationships between variables, expressing influences that they have on each other, either positive or negative. Each causal link is described by an algebraic sign that shows either the direct (positive) or inverse (negative) proportionality between each couple of elements. The fundamental utility of a causal loop diagram is mainly a conceptual one, but it also helps in identifying some important archetypical structure and thus some typical expected behavior [2, 3].

Moreover, cycles which appears in the graph G are called causal feedback loops, and they may be of two types, Reinforcing Feedback Loops (tend towards instability) and Balancing Feedback Loops (which tend instead towards a stability of the system).

The digitization process in the Public Administration has been therefore studied through the creation of a causal map (which has then been interpreted in terms of stock and flow diagrams) by analyzing the problem of the adoption and diffusion of the New Technology, basically making use of the Bass Model (effective adopters of the new technology grow in number since they tend to spread into the relevant population and thus the "epidemic" contact becomes more and more likely to happen). We also introduced some aspects like the word of mouth effect as well as the influence that a marketing campaign may have. Another fundamental aspect that we considered is the perception of the advantage introduced by the new technology, which basically connects the world of the documents with the world of the users. Other elements of crucial importance are the "savings" in terms of costs and in terms of time.

A variable expressing the level of unsatisfaction of the users has not been reported in the map (and therefore in the model) since we reckon that once the economical and financial effort has been made there is no point in abandoning the new system: it would be a great loss of money.

Here follows the complete causal loop diagram:

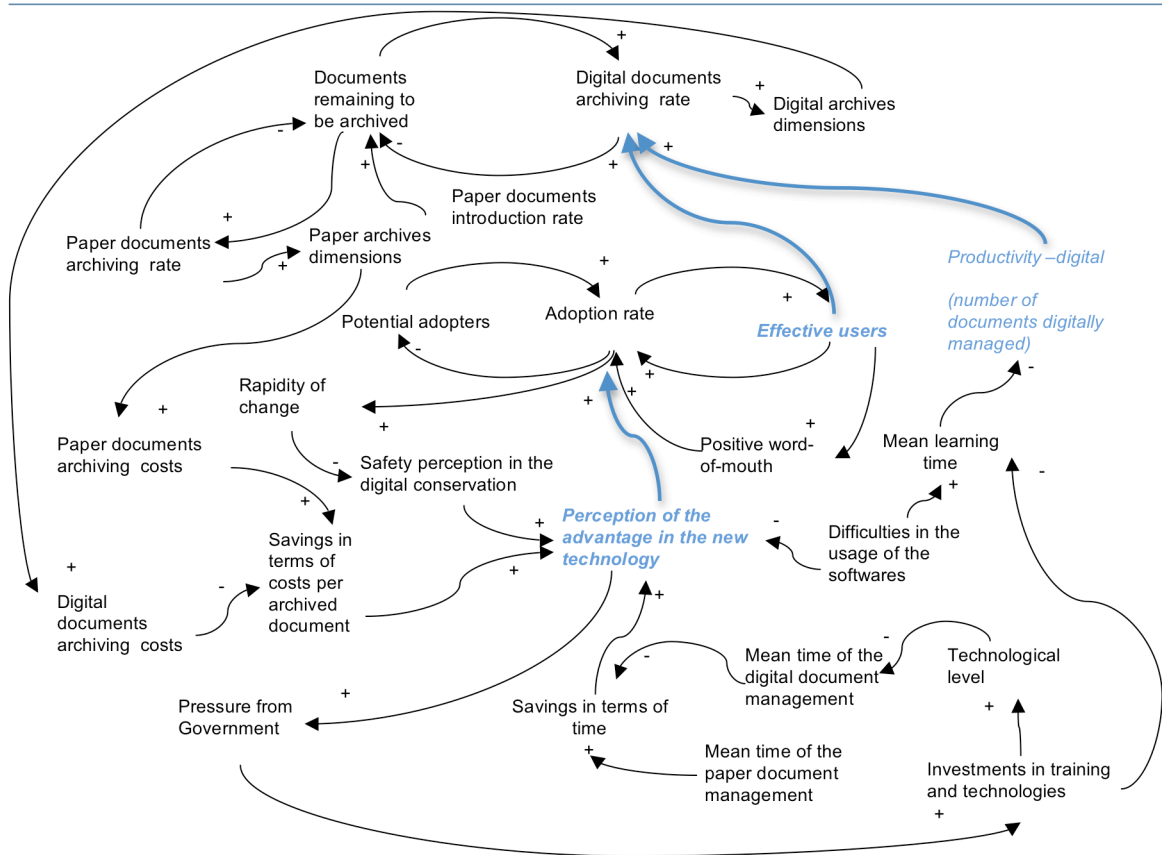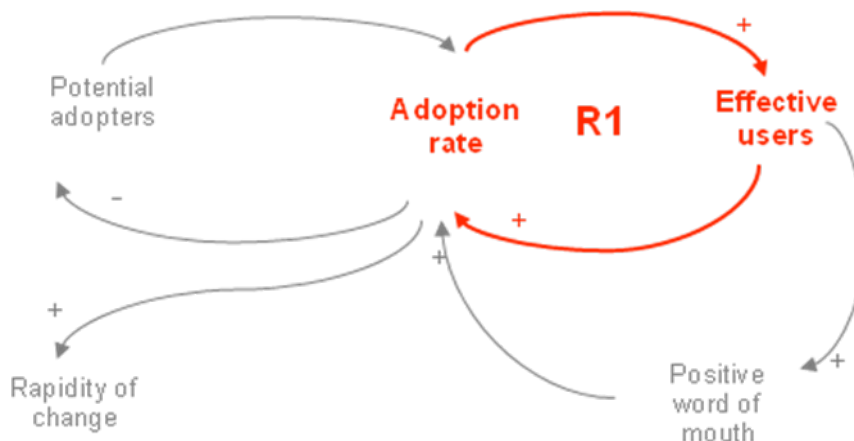# OVERALL CAUSAL LOOP DIAGRAM

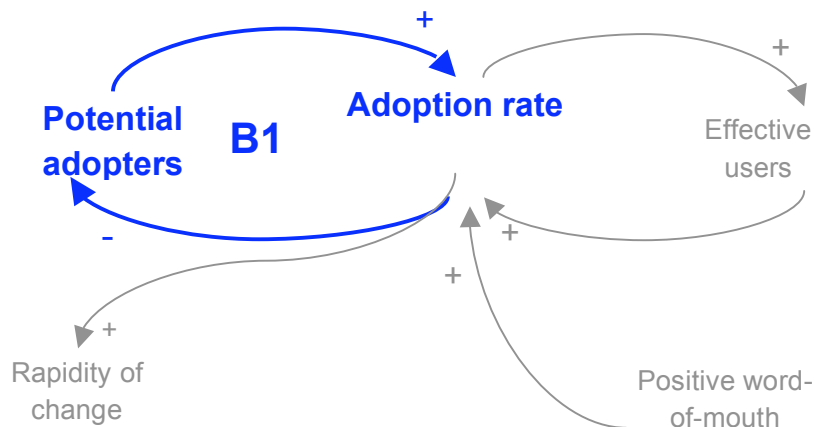**Figure 1 The Causal Loop Diagram**

The relations among the reported systemic variables have been validated by experts at CNIPA, as well as also by previous studies [1]. More in detail, we will now delve into the various feedback loops of the overall causal map.

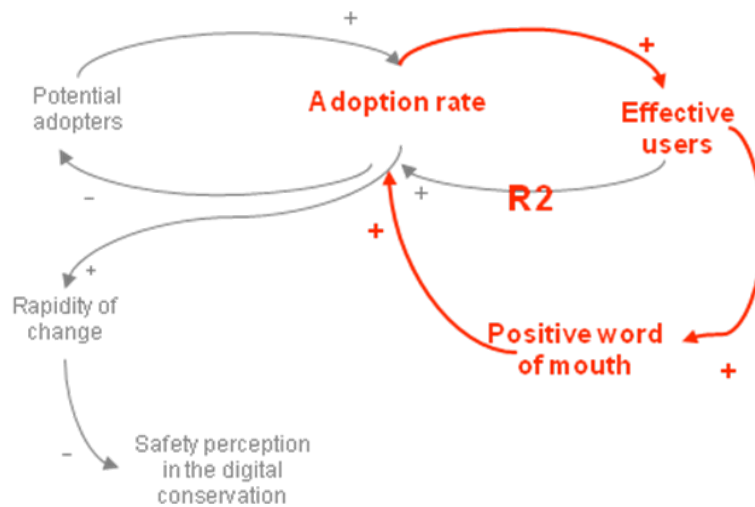## R1 Mutual positive influence between effective users and adoption rate

The first reinforcing feedback loop shows how the number of effective users grows when the adoption rate increases and vice versa: the more people adopt the new technology, the more the adoption rate grows because potential adopters are highly encouraged to adopt it. This is what usually happens with every new technology: in this case, the more people there are to exchange digital documents with, the more a person is encouraged to get digital devices and adopt the new system. It depicts a sort of trend effect.

B1 The decrease of the number of potential adopters as the adoption rate rises
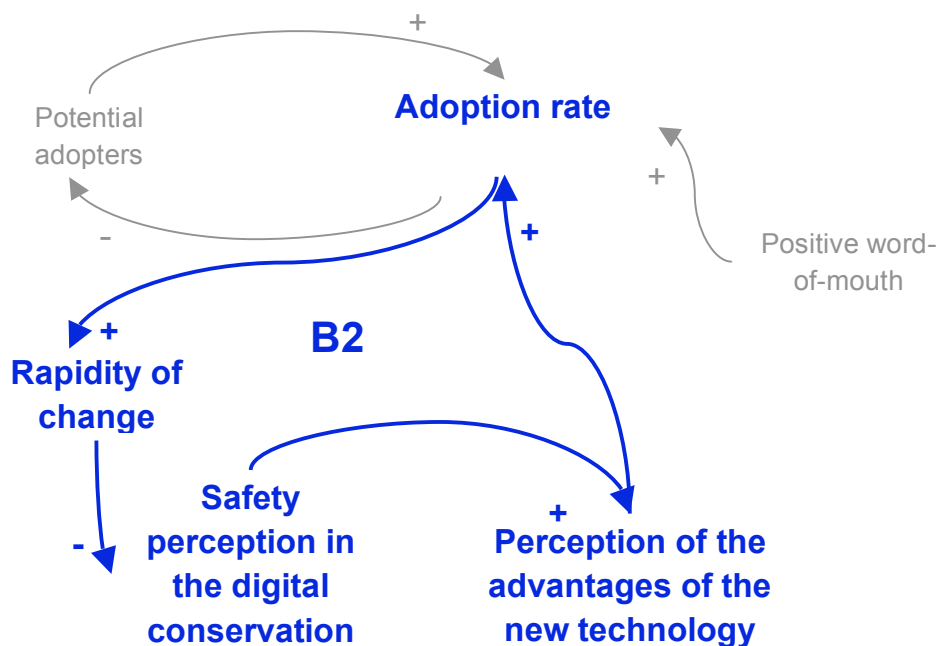

As the adoption rate grows the number of the potential adopters decreases because they turn into effective users. On the other hand if the number of potential adopters grows, so does the adoption rate, since more people can be influenced.

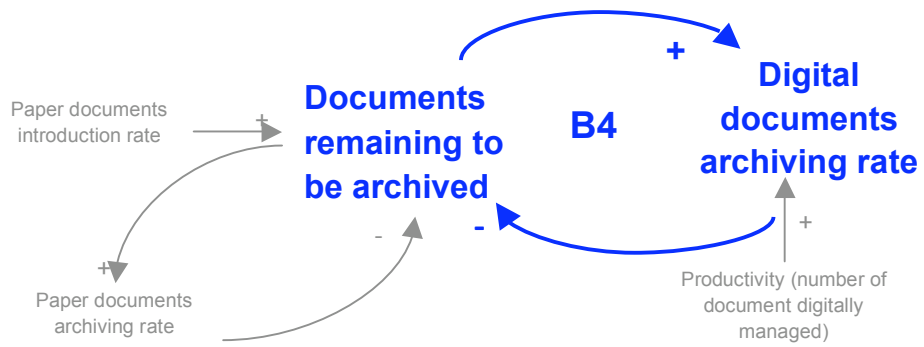## R2 The reinforcing action of the positive word of mouth

The larger the number of effective users gets, the bigger the effect of the word of mouth is, which consequentially leads to an increase in the adoption rate.

B2 The balancing action of the change in technology

If the adoption rate grows then there are higher incentives to develop new technologies (it is what happens for instance in the mobile telephone field: the more people appreciate the new item, the more the Companies create always newer functions, thus developing new technologies), which creates a certain lack of safety perception in the digital conservation. This is basically due to the fact that a document that today is written on a technological support, could be not readable tomorrow on

a new support. The user thus loses perception of advantages due to the adoption of the New Technology.

R3 The positive action of Government support

The positive influence of the Government on the process of adoption of the new technology, which consists in great investments in different fields, improves the management of the digital documents, basically in terms of time, and increases the perception of the advantage of the new technology.

B3 – B4 The decrease in the number of documents to be archived as the archiving rates grow
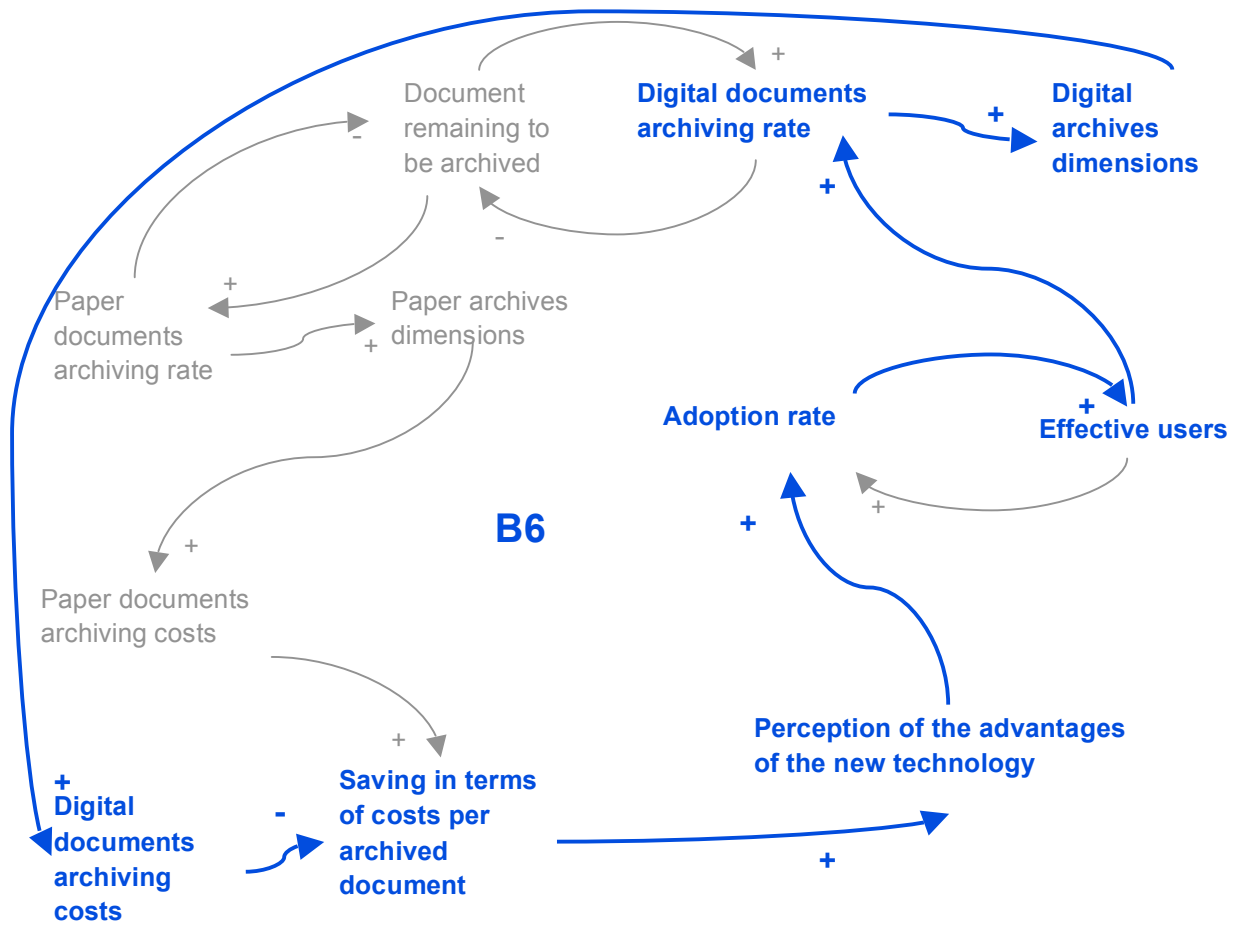
The number of documents to be archived obviously decreases as the archiving rates of the documents, both paper and digital, grow. In the "documents remaining to be archived" it is not specified in which format the documents will be archived (they will all be archived in paper archives, but a part of them also in digital ones). This depends on how much the new technology has spread and in which percentage the documents are digitized.

Here also follow the biggest feedback loops, in which the balancing action of the creation of digital archives, the digital archiving costs and the mean learning time on the adoption process is shown.
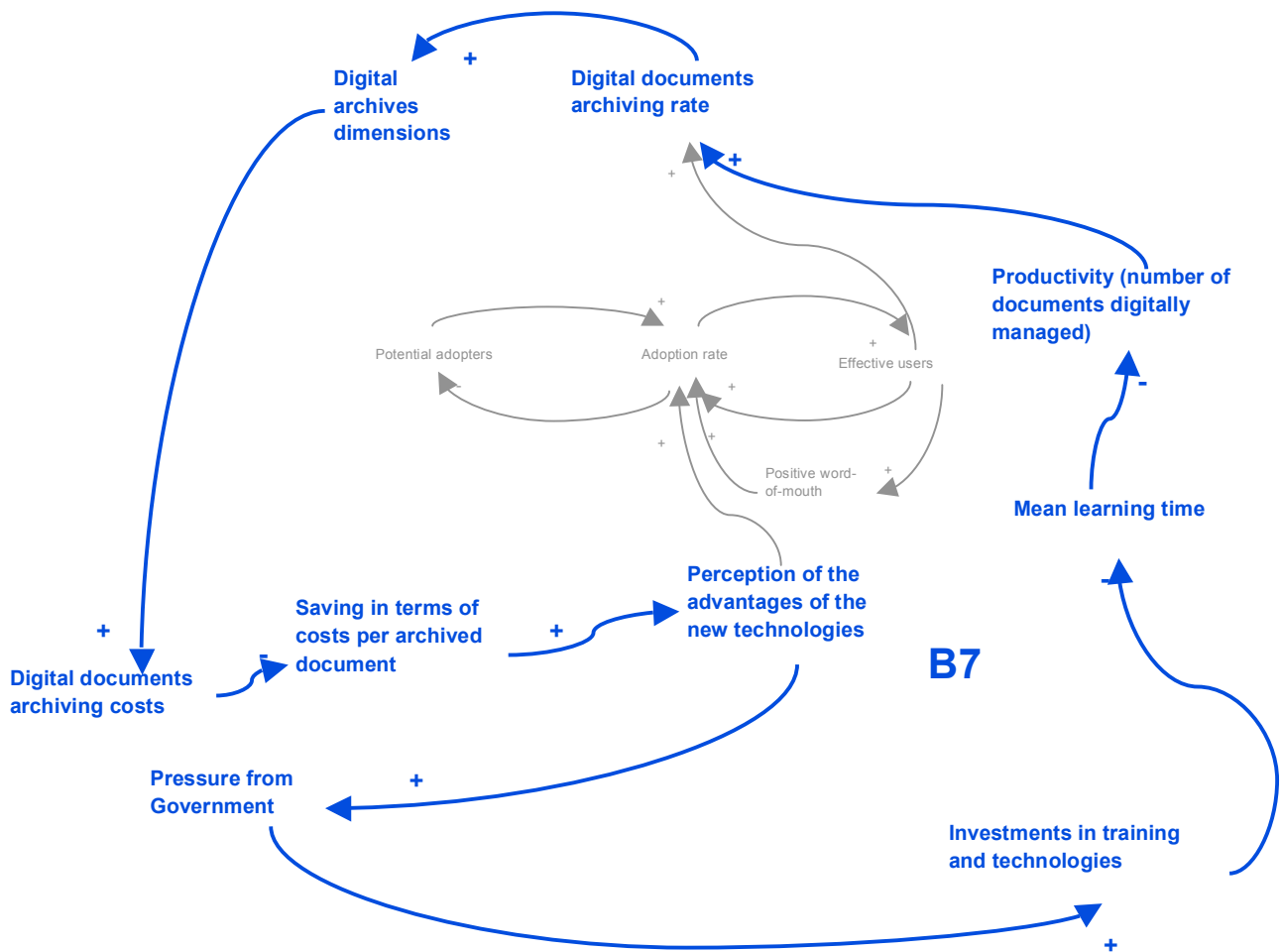
B5 The influence of the creation of digital archives on the adoption process

Documents remaining to be archived

+

Digital documents archiving rate

+

Paper documents introduction rate

-

+

Paper documents archiving rate

+

Paper archives dimension

-

+

Effective users

Adoption rate

+

+

Rapidity of change

+

B5

+

+

Paper documents archiving costs

-

Safety perception in the digital conservation

Positive word-of-mouth

+

+

+

Saving in terms of costs per archived document

Perception of the advantage of the new technology

+

+

B6 The balancing action of the digital archiving costs on the adoption process

Document remaining to be archived

+

Digital documents archiving rate

+ Digital archives dimensions

-

Paper documents archiving rate

+

Paper archives dimensions

+

-

+

B6

+

Adoption rate

+

Effective users

Paper documents archiving costs

+

Perception of the advantages of the new technology

+

Saving in terms of costs per archived document

-

+ Digital documents archiving costs

+

B7 The balancing action of the average learning time on the process of digitization

4. Model description

The causal loop diagram is a valid starting point for the creation of a stock and flow model, that is a System Dynamics (SD) model. The main SD "building blocks", or elements, like stocks/level, flows, rates, auxiliary variables and constants all contribute to build and deeply analyze the context that surrounds the document elaboration procedures, both inside and outside the Public Administration, thus making it possible to formalize quantitatively what we have previously described in the causal map. At the end of the simulation of the model it is immediate and clear the visualization of those problems which may arise in the long term period, or those variables upon which we should insist to make it easier to spread the new technology and switch to the new procedures [18, 21, 24, 25].

However, the implemented model basically describes three main processes: the technology adoption, which shows and underlines the drivers of adoption and the time space that the fully adoption itself would take; the archives dimensions, with particular attention to the cost cutting solution that the digitization process would convey; the model of governmental influence, regarding the reforms in this field and the financial budgets and investments to support the digitization process.

The users model is based on the Bass model [25], that we have modified to make it highly representative of the real situation concerning digitization.. In the Bass model the total adoption rate is the resulting contribution of adoptions coming from positive word of mouth and adoptions coming from advertising. Bass assumes that when the new technology has not spread yet (the effective users set is empty) the only driver of conversion is an external source like advertising. On the other hand as the effective users grow, the action of positive word of mouth will consequentially increase.

 The most significant change refers to the adoption rate, which is influenced by the adoptions from word of mouth and the adoptions from advertising, but also and more intensely by the perception of the advantage in the new technology. Advertising is meant as a driver of adoption because we assumed it includes an action of encouragement to adopt the new technology at different levels and not only advertising in the literal sense of the term. It refers, in fact, to what has been identified as investments in training and technology and pressure from the Government in the causal loop diagram.
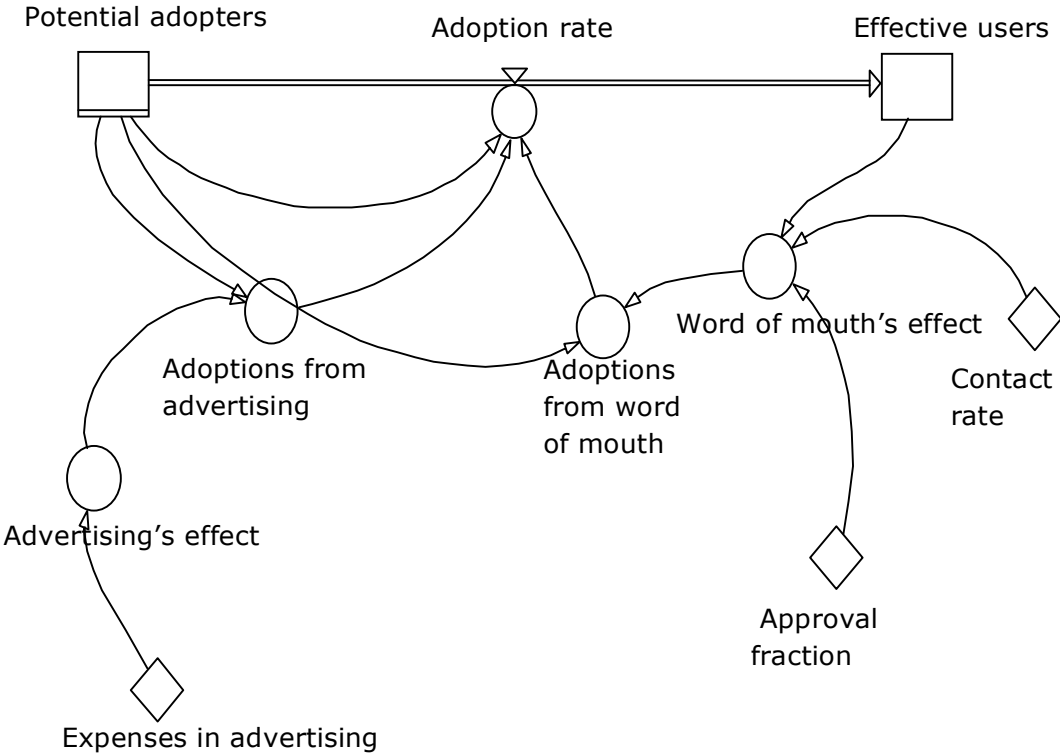
Figure 2 The users model

In the documents model the fundamental variables whose behavior we have underlined are the dimensions of the archives, both paper and digital, which are represented by the number of documents archived in either format.
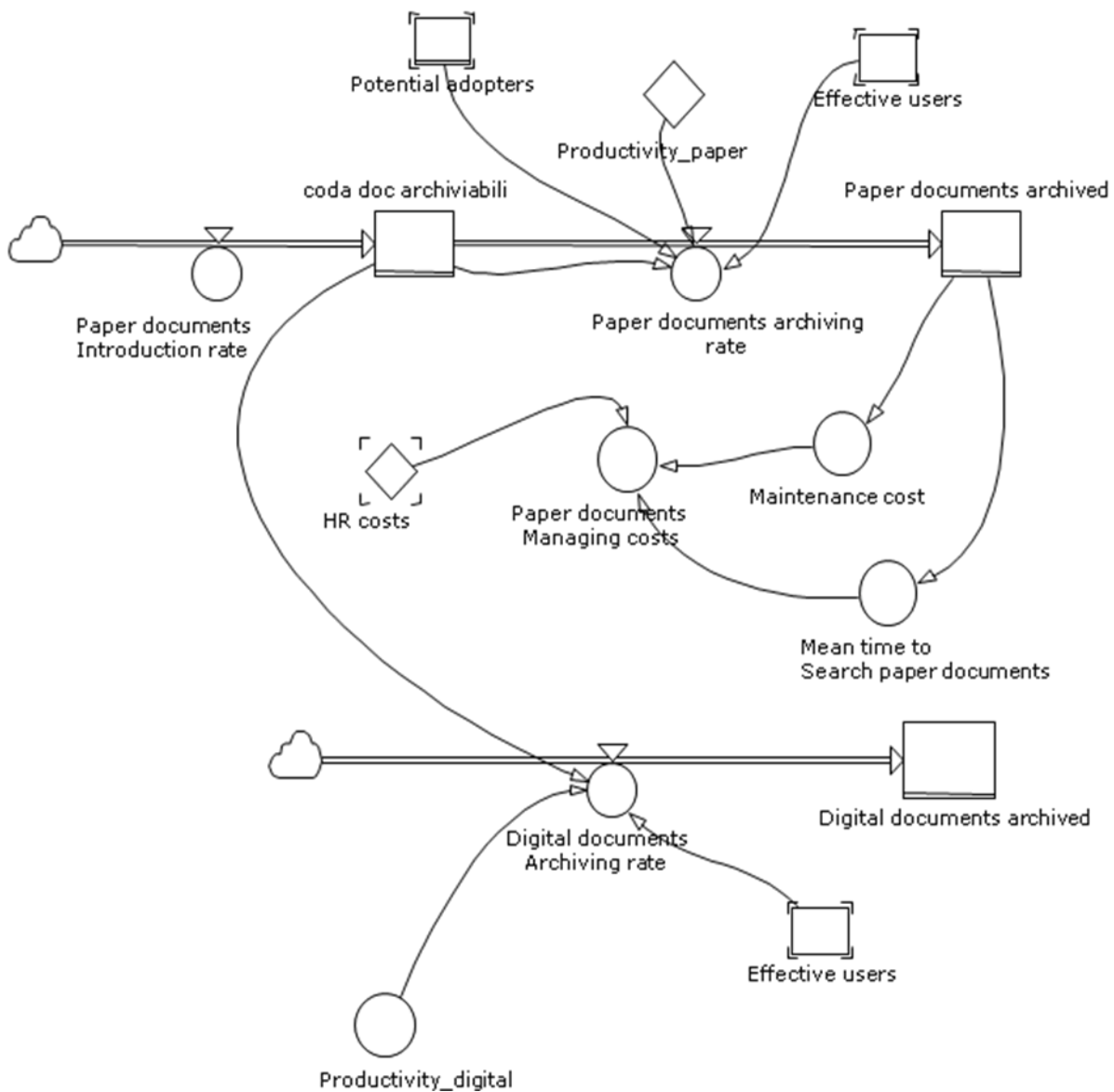
Figure 3 The documents model

In the costs model, two types of costs are shown: archiving costs and managing costs. The former, which we have considered as constant costs in both cases, show an immediate saving, while the latter, which are influenced by other systemic variables, will show an economic advantage in the long term period.
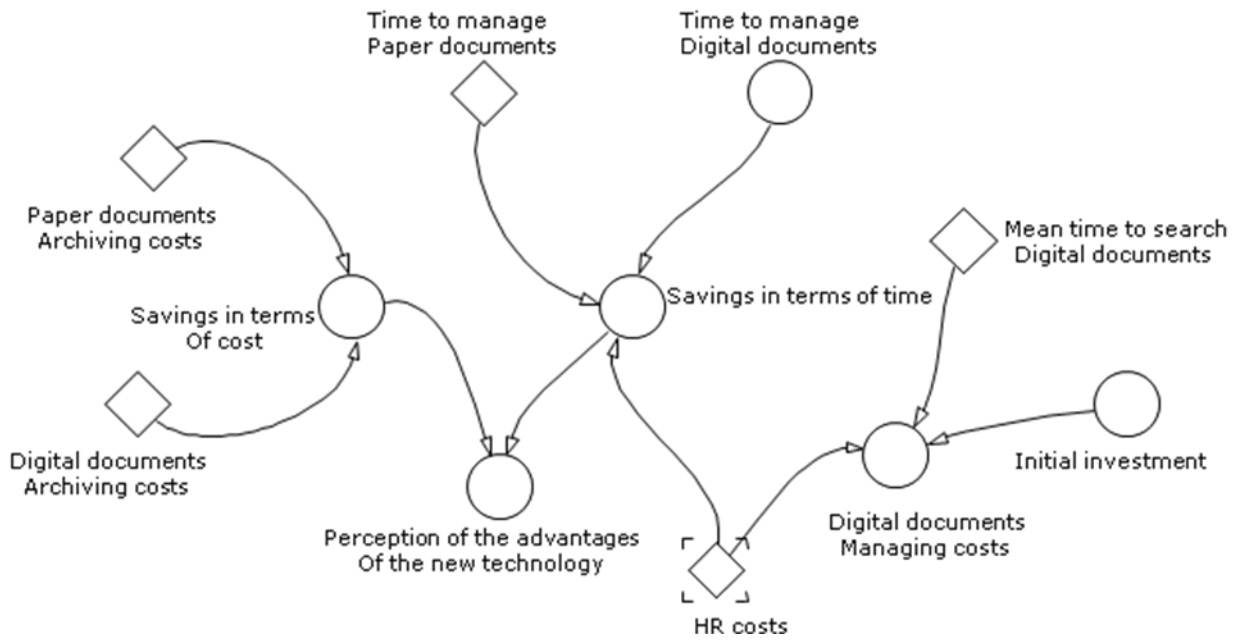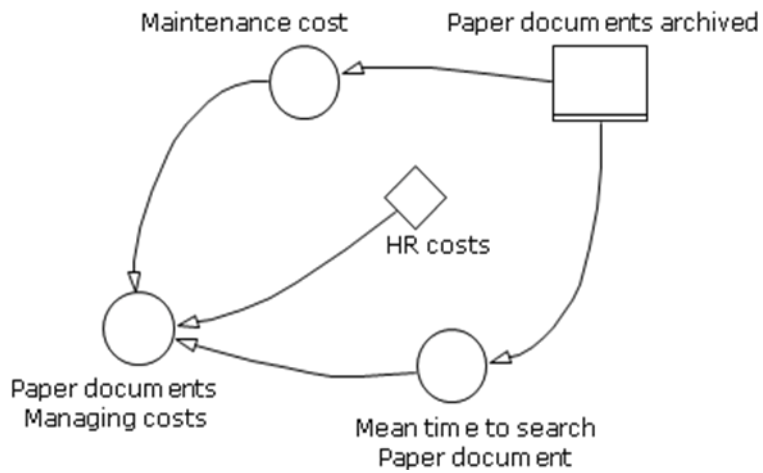
Figure 4 The costs model

Figure 5 The costs model

As shown in the following picture, the Government action consists of the economic support in training and technology: at least in the first years of the diffusion of the digitization this kind of support is definitely needed, both as an encouragement to adopt the new procedures and to effectively financially help the administrations in the "conversion" process.
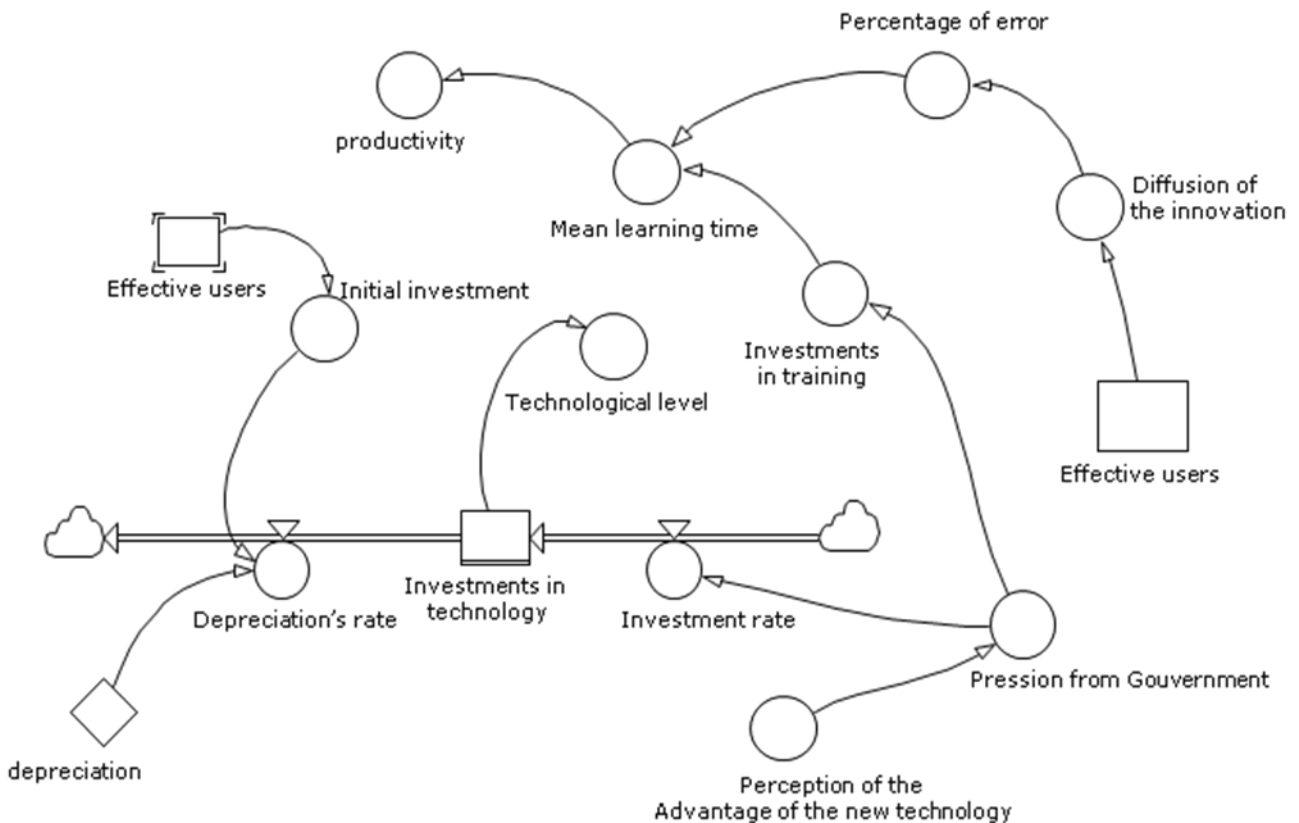
Figure 6 The investments model

5. Simulation results

In the first place, we put the systemic variables under the so called condition of "simulation stress", so that we could provide realistic and acceptable values for them. The time space considered for our simulation scenery is ten years.

After a few simulation runs, the values of the input variables have been chosen according to the following assumptions:

- Contact rate 20% - 30%

- Approval fraction 4% - 6%

- Expenses on advertising 200000 – 300000 Euros

- Paper document archiving cost 18 Euros

- Digital document archiving cost 9 Euros

- HR cost 0,15 – 0,20 Euro/min

- Mean time to search digital documents from the archives 1 – 5 minutes

- Paper document average managing time 35 – 40 minutes

The output variables that we have chosen to analyzed are the number of effective and potential users, the adoptions from the two drivers (advertising and word of mouth), the dimensions of the archives, both paper and digital, and the managing costs of the archives, which give an immediate perception of the economical advantage brought by the digitization.

The final results have then been discussed and approved by CNIPA experts and they are shown as follows.

As far as the users and technology diffusion model is concerned, here is the final state of the simulation:
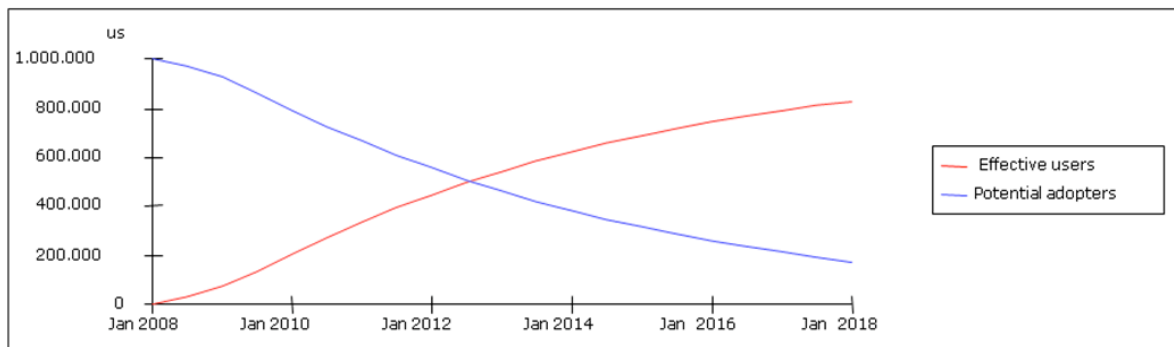

Figure 7 Users model simulation

Soon after the fourth year of the simulation the number of effective users dominates the number of the potential adopters and the new technology is already well spread. At the end of the tenth year of the simulation more than 90% of the potential adopters have chosen to move to the new technology.

Further details are shown in the following charts:

Time	potential adopters (us)
Jan 1st 2008	1.000.000,00
Jan 1st 2010	796.939,43
Jan 1st 2012	612.114,17
Jan 1st 2014	491.776,58
Jan 1st 2016	407.073,08
Jan 1st 2018	344.213,77

Time	effective users (us)
Jan 1st 2008	10,00
Jan 1st 2010	203.070,57
Jan 1st 2012	387.895,83
Jan 1st 2014	508.233,42
Jan 1st 2016	592.936,92
Jan 1st 2018	655.796,23

As shown in figure 8, the drivers of adoption act in two different time periods: when the number of potential adopters is still very high, the advertising action is much stronger than the word of mouth's.
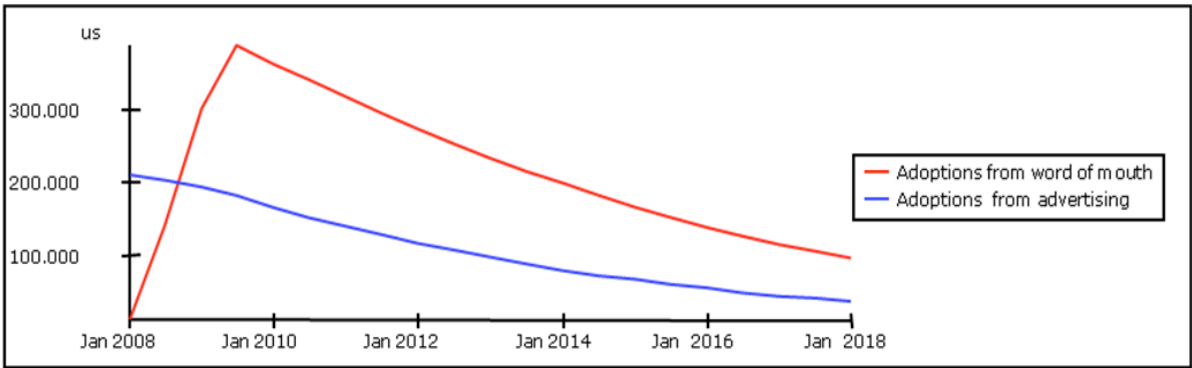
Figure 8 Users model simulation

On the other hand, as the number of effective users rises, the action of the positive word of mouth totally dominates the advertising effect. Further details are shown in the following charts:

Time	adoption from advertising (us)
Jan 1st 2008	240.000,00
Jan 1st 2010	191.265,46
Jan 1st 2012	146.907,40
Jan 1st 2014	118.026,38
Jan 1st 2016	97.697,54
Jan 1st 2018	82.611,31

Time	adoption from word of mouth (us)
Jan 1st 2008	120.004,16
Jan 1st 2010	314.843,27
Jan 1st 2012	171.754,03
Jan 1st 2014	101.334,90
Jan 1st 2016	62.525,02
Jan 1st 2018	39.468,86

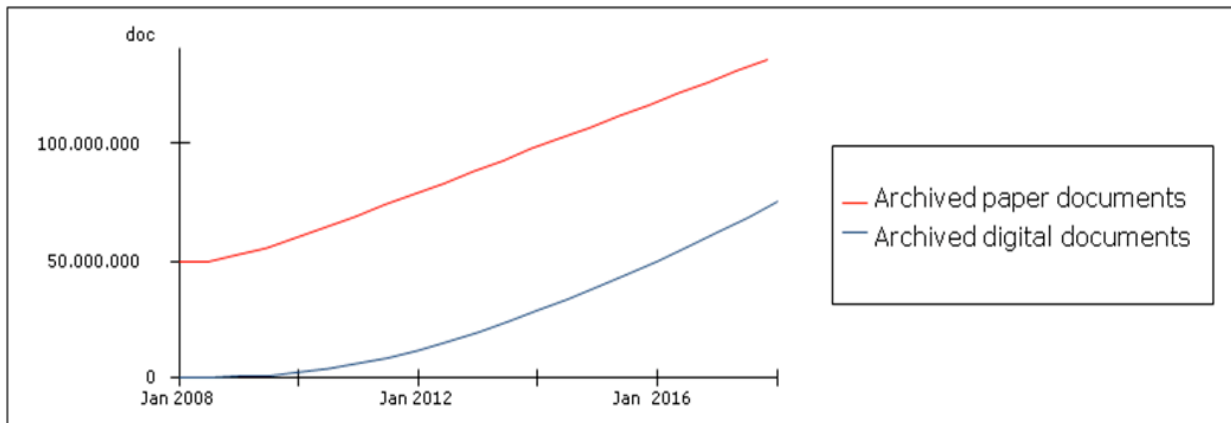As far as the documents model is concerned here follow the simulation results:

Figure 9 The documents model simulation

The simulation shows how the gradient of the curve representing the digital documents never dominates the gradient of the one representing the paper documents, but this is just right and totally expected because the simulation has been made under the hypothesis that all the incoming documents are in the paper format and therefore must be archived in paper archives. However, a significant and rapid growth of that gradient shows how the dematerialization acts on the archives dimensions and also shows the great advantage that could be achieved with the drastic reduction of the dimensions of the paper archives, once the percentage of electronic incoming documents will rise.

Further details are shown in the following charts:

Time	paper documents archived (doc)
Jan 1st 2008	50.000.000,00
Jan 1st 2010	60.625.937,50
Jan 1st 2012	80.040.058,59
Jan 1st 2014	100.003.441,16
Jan 1st 2016	120.001.152,57
Jan 1st 2018	140.001.009,54

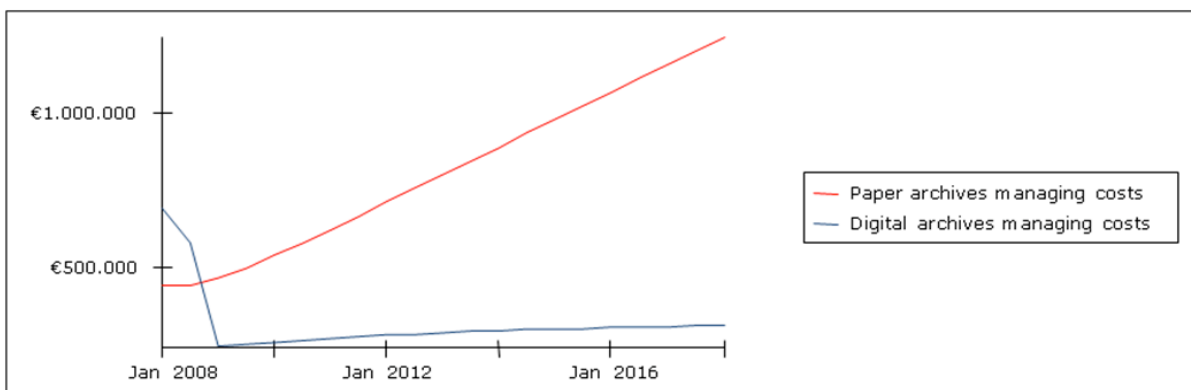| Time	digital documents archived (doc)
Jan 1st 2008	10,00
Jan 1st 2010	2.525.467,00
Jan 1st 2012	13.245.953,91
Jan 1st 2014	30.050.516,78
Jan 1st 2016	50.943.878,77
Jan 1st 2018	74.773.484,97

Figure 10 The costs model simulation

In Figure 10, we can appreciate an evident economic advantage that could be achieved with the digital procedures. Apart from the initial investment, in fact, the paper archives managing costs are much higher than the digital ones and more specifically they keep growing at a much higher rate. An element that should be noticed is that the initial value of the paper archives costs depends on the initial dimension of the paper archives, which has been arbitrary chosen. But what really matters is the gradient of the curve to be compared with the digital one and the result is evident.

Further details are shown in the following charts:

Time	paper archives managing costs
Jan 1st 2008	€ 445.861,78
Jan 1st 2010	€ 540.615,12
Jan 1st 2012	€ 713.734,22
Jan 1st 2014	€ 891.751,19
Jan 1st 2016	€ 1.070.074,27
Jan 1st 2018	€ 1.248.416,49

Time	digital archives managing costs
Jan 1st 2008	€ 690.003,20
Jan 1st 2010	€ 260.964,05
Jan 1st 2012	€ 276.776,57
Jan 1st 2014	€ 287.071,91
Jan 1st 2016	€ 294.318,63
Jan 1st 2018	€ 299.696,48

6. Conclusions

Here follows what emerges from the present analysis.

As far as the Italian Public Administration is concerned there are a few points that need to be clarified from the juridical point of view, particularly about the discard problem.

Consequential to the discard problem is the fact that the amount of paper that is currently present in the system cannot be dismissed. In order to prevent us from dealing with bigger and bigger archives, which constitute one of the major problems of the documental management, is therefore absolutely needed to cut down on the production of paper documents, switching to the digital procedures.

Moreover the digitization process would imply a much less intense environmental impact, due to the minor production of paper and the limited space needed to store documents, and a relevant time reduction achievable with the new procedures. This would also lead to a higher productivity of HR.

From an economical point of view, the results show that the documents digitization would definitely lead us to relevant savings, as shown in the simulation results. In fact, once the initial investment is absorbed, the managing costs are almost irrelevant: they are the costs of regular secure back ups, conversion to an ever changing technology, and training of people to do this type of work, which is a constant re-investment, but definitely small compared to the advantages that the new system brings.

On the other hand major action should be taken to lead the population to switch to the new system: the adoption must be encouraged by the institutions, since a reluctant attitude towards changes can be certified in the Italian population. The documents digitization would modify a great part of procedures, roles and competences regarding documents management and this makes it easy to understand the reasons of a possible resistance. Nevertheless what 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.

Our study has been carried on under some limiting assumptions without, however, losing interest or validity in its results. It can be considered as a valid starting point for further studies, which definitely should be made on a more detailed basis, considering, for example, unsatisfied adopters in the users model or the production of digital documents in the documents model etc.

7. References

1.   Armenia S., Canini D., Casalino N. *A system dynamics approach to the paper dematerialization process in the Italian public administration*, Venezia, itAIS 2007 - IV Italian Conference of the Italian Chapter of AIS, 3-7 October 2007 in The Interdisciplinary Aspects of Information Systems Studies, to appear, Springer, Heidelberg, Germany, ISBN 978-3908-2010-2.

2.   J. R. Burns, *A matrix architecture for development of system dynamic models*, 2002

3.   J.R. Burns *A component strategy for the formulation of system dynamics models*, 2002

4.   Giancarlo Capitani, *Politiche e strumenti per l'impresa digitale*, november 2007 (www.netconsulting.it)

5.   CNIPA Notebook N.24 "La dematerializzazione della documentazione amministrativa" (The dematerialization of administrative documentation)

6.   CNIPA, Norm evolutions on the subject of Administrative Documentation (1990 - 2005)

7.   CNIPA, inter-Ministerial Workgroup on document dematerialization by means of electronic formats, *White Book on document dematerialization in the italian public administration*, March 2006

8.   A.M. Colombo, L. De Francesco, *Analisi del ciclo di vita e del contesto relativi al documento amministrativo*, Master Degree Thesis, Rome, July 2007.

9.   ENEA, *Progetto Formazione a distanza, Sistema Qualità: Pensiero Sistemico*, Integra Module, (http://odl.casaccia.enea.it)

10. T. S. Fiddaman "Exploring policy options with a behavioural climate-economy model"-system dynamic review - vol 18.2

11. J.W.Forrester, *System Dynamics and Learner-Centered-Learning in kindergarten through 12th grade education*, Massachusetts Institute of Technology, Cambridge, December 1992.

12. J.W.Forrester, *Technology Review: Counterintuitive Behavior of Social System*, Massachusetts Institute of Technology, Cambridge, January 1971.

13. B. Gates, *A road to tomorrow*, Mondadori,

14. W.Glass Husain, *Teaching System Dynamics: Looking at Epidemics, System Dynamics in Education Project*, October 1991

15. R. Hanneman *Modeling dynamic social systems* – computer-assisted theory bulding-

16. G. Longobardi *Analisi dei costi per l'automazione della funzione documentale* (Cost Analysis on the automation of document production)

17. D.H. Meadows, *The Global Citizen*, System Dynamics Meets the Press, Washington DC, 1991

18. J. D. W. Morecroft J. Sterman *Modeling for learning organization*

19. Alessandro Narduzzo, *Processi e pensiero sistemico*, (http://pro.unibz.it)

20. G. Ossimitz *Development of systems thinking skills*

21. M. J. Radzicki *Foundation of system dynamics modeling*

22. P. Ridolfi, *La dematerializzazione dei documenti: idee per un percorso* (*Document dematerialization: ideas for a roadmap*), 2005

23. Pierluigi Ridolfi, *Dematerializzazione e Semplificazione dei Procedimenti: l'Innovazione Possibile*, Torino, 19 giugno 2007 (www.forumpa.it)

24. P. Senge, *The Fifth Discipline*, Sperling & Kupfer, 1992

25. J. D. Sterman, *Business Dynamics - System thinking and modelling for a complex world* - Irwin McGraw Hill, 2000

26. J. Sterman, *All models are wrong: reflections on becoming a system scientist*

27. J. Sterman, *Instructors' Manual for Business Dynamics*

WEB:

28. www.issesystems.com

29. www.powersim.com

30. www.public.asu.edu/kirkwood/sysdyn/SDRis.htm

31. www.rtis.com

32. www.systemdyanamics.org

33. www.systems-thinking.org

34. Free Enciclopedia Wikipedia (http://it.wikipedia.org)

35. CNIPA – Centro Nazionale dell'Informatica nella Pubblica Amministrazione – www.cnipa.gov.it