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DECISION SUPPORT FOR REGIONAL TELEHEALTH INTEGRATION: A SYSTEM DYNAMIC APPROACH

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ABSTRACT

The purpose of this article is to use System Dynamics approaches for decision support. Telehealth is proposed in many articles as one of the possibilities to answer the challenges of keeping and reinforcing the goodness and fairness of the healthcare systems. But very few studies focus on predicting telehealth integration in the current healthcare system. The model proposed in this paper simulates several scenarios of telehealth integration in order to reduce healthcare cost and save valuable medical time. It also highlights the main factors that have the most influence on the results and provides help for healthcare managers to choose between different strategies and healthcare policies.

Keywords: decision making, system dynamics, systems engineering

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1 INTRODUCTION

Healthcare systems in occidental countries are facing intense challenges to keep and reinforce their value of goodness and fairness (WHO s. d.). Telehealth can be proposed as one of the possibilities to answer these challenges (Davalos et al. 2009; Uwe 2010; Le Goff-Pronost & Sicotte 2010). But very few studies focus on predicting telehealth integration in the current healthcare system. System dynamics is considered to be an interesting approach to support decision-making and predictive modeling incorporating quantitative and qualitative data. In this paper, in order to investigate the sustainability of telehealth integration, we propose a System Dynamics (SD) simulation model for early design decision making. The aim of the model proposed is to link influencing factors such as the number of people aged more than 60 years old, the demographic of medical staff and the healthcare cost. The simulation model is set to the 2010 conditions in a French region named Picardie and run for a period of 30 years until 2040. We propose to integrate scenario-based simulation in order to provide a decision support investigation of potential solutions to reduce healthcare cost and save valuable medical time.

2 LITERATURE REVIEW ON SYSTEM DYNAMICS AND HEALTHCARE

Complex systems are systems whose size, dependence on context, variety of elements and their interdependence makes unpredictable and therefore difficult to manage. Making decisions within and concerning those systems is always difficult due to the unanticipated result that can occur.

As healthcare systems are complex ones, decision making are mostly difficult. For example, making decisions on the closure or conversion of hundreds of hospital beds, on the introduction of new medical references for reimbursement in the State Medical Classification, on giving permission of use for new drugs or on the incorporation of telehealth technology in the current healthcare system are complex issues. Thus, providing decision support for healthcare managers can help them to opt between different policies.

System dynamics have been identified as an interesting tool in the field of healthcare system modeling and prediction. It is an analytical modeling approach translating operationally the System Thinking theory stemming from the approaches such as the theory proposed by (Simon 1969; Bertalanffy 1993; Le Moigne 1985). System Dynamics was developed by Jay Forrester at MIT during the mid-1950s with his work on Industrial Dynamic (Forrester 1999). The main advantage of this approach is to model and take into account multiple feedback loops, delays and nonlinearity between variables. The objective is to analyze, understand and predict the behavior of complex systems by analyzing its changing factors (Sterman 2000). Despite the fact that the comparison with other modeling techniques such as Markov chains (Honeycutt et al. 2003) or multi-agent systems (Huang et al. 1995) is difficult, system dynamics models are generally considered broader, incorporating a larger number of variables and delays in causal relationships (Jones & Homer 2006).

This method has been, since the 1970s, used in many areas of health. In 2005 (Koelling & Schwandt 2005) analyze the bibliography of the use of System Dynamics (SD) for Healthcare between 1965 and 2004. They indicate an increasing interest to study health system with this tool. They also made a classification and show that the literature has a strong interest on strategic and policy studies at international, national and regional level (76% of the articles). The other categories concern prevention of illness, disease, or incidents and the impact of prevention strategies and tactics (20% of the articles). Epidemiology studies use also SD tools to study the spread and the physiological understanding of illness and disease.

The articles of (Erdil & Emerson 2008) and (Brailsford 2008) outline the added value of using SD tools to provide help for healthcare managers to choose between different strategies. The first one proposes a model of adoption of Electronic Health Records in the US. The use of System Dynamics helps to identify the real barriers and factors that have to be changed to speed up the adoption process. In the second one, (Brailsford 2008) compares short term savings by future increase for Social Services care in order to quantify the reduction of the expected benefit. Scenarios were proposed to change the actual policy.

Previously discussed research studies show examples of SD models and their importance in the healthcare system transformation. Our research study aims at investigating the integration and impact of novel technologies, telehealth, in the current healthcare system. Although the importance of the telehealth have been discussed in various occasions (Davalos et al. 2009), (Uwe 2010), (Le Goff-

Pronost & Sicotte 2010)), no modeling has been proposed to predict this integration and future system transformation. Main objective of this model is to support French government in decision support for telehealth with identified time span of 30 years. We propose also to integrate Systems Thinking as a base for developing and testing SD models. The proposed research design will be further explained in the section 3.

3 STUDY OBJECTIVES

We propose to consider telehealth as a system and to model it thanks to the definition of the system adapted from Le Moigne, (Schindler et al. 2007): "A system is an object, which in a given environment, seeks to achieve goals (teleological axis) performing activities / processes (functional axis), and while its internal structure (ontological axis) evolves over time (genetic line), without losing its own identity" (figure 1). This definition has been already used to describe healthcare system for gerontology technologies (Zimmer 2009) or in healthcare R&D (Schindler et al. 2008).

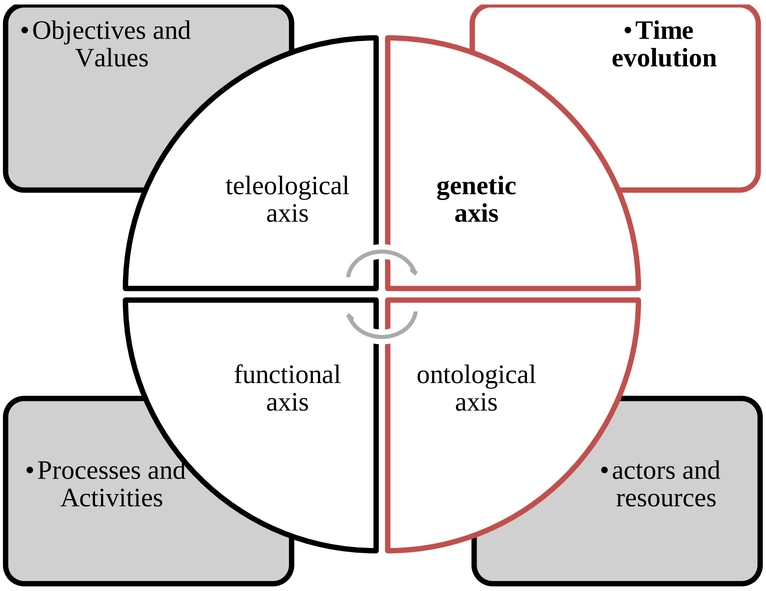


Figure 1: System definition (adaptation of Le Moigne, 1991)

Previous articles (Jean et al. 2011; Jean et al. 2012) deal with the proposition of objectives and values modelling for the telehealth integration in the healthcare system (teleological axis). Furthermore, they propose a support to define internal structure by stating its actors and its resources (ontological axis) and to design the needed processes to actualise the values (functional axis).

The last axis that needs to be studied is the genetic axis. In order to simulate over time the change of other axis during the system life-cycle, SD tools can help modelling different scenarios corresponding to different strategic, tactical and operational decisions. In fact, change of the organization's mission and long-term goals (strategic decision), support of strategic plans by choosing the relevant activities and their quantities (tactical decision) and dimension the resources needed (operational decision) can be model by SD tools.

The model proposed in this paper can simulate several scenarios of telehealth integration. It gives an answer for the decision makers about the importance and the efforts that have be done each year in function of the cost reducing and on the saving of medical time required. It also helps to highlight the different areas that have the greatest importance for these last two variables.

In this article, the two research questions we sought to answer specifically are:

1) *Which scenario of overall usage rate is the best one to keep the budget and the equity indicators satisfactory?*

2) *What are the main "action domains" where special efforts have to be made to influence more effectively budget indicator? The action domain will be defined in section 4.2.*

Future work will investigate other scenarios to simulate for example the different policies that were elicitated and discussed with healthcare managers: the ones incitation with the support for material purchasing and maintenance and the support for medical network design and change management; and the penalty policies through a decrease in transport reimbursement for the establishments that are not using telehealth. These policies determine the overall usage rate of telehealth stations that we are studying in this article.

4 EXPERIMENTAL SETTING AND VARIABLES

After a short presentation of telehealth, our research design is described and the details about the experimental setting and the variables are provided.

4.1 Telehealth

Medical desertification is a reality. For example, in the Meru local hospital (France) there were five specialized doctors in 2007, and there are none today. Without telemedicine, patients are forced to be transported more than 30 km to reach a larger hospital where there are still specialized doctors. This phenomenon will grow in the future and telemedicine is a way to reorganize the health territories.

Telehealth is the use of information and communication technology to deliver health and social care (Barlow et al. 2006). Its main idea is to provide a remote access of healthcare services thus closing the distance with appropriate healthcare professionals (Jean et al. 2012). It supplies a multidisciplinary network of professionals of different levels (general practitioners, specialized doctors) in order to give appropriate care of patients. It is based on interprofessional collaborations and requires prerequisites and rules of good practice.

In France, three applications of telemedicine are defined by law (Legifrance, Decree No. 2010-1229, 2010):

1 The teleconsultation that provides the ability to see 0a doctor at distance. A healthcare professional may be present with the patient to assist the doctor during the teleconsultation.

2 The teleexpertise that aims solicitation of the opinion of one or more colleagues for their training or enhancement of their skills.

3 The teleassistance that aims to enable a physician to attend at distance another physician or health professional during the performance of an act.

Telehealth stations can consist of a main screen and two related screens: one connected to the radiology and medical records; and the other one connected to the biomedical equipment for exchanging digital information (camera hand electrocardiograph, spirometer, dermatoscope, otoscope, and ultrasound) (Espinoza et al, 2011). Secure networks have to link the stations to protect the data transmitted.

The figure 2 represents the south-west of the Picardie region. On the right side are the hospitals. In few years, only the main one in the center will have specialized doctors and there is right now no hyper-specialties like neurology. People have to do more than 30 km to reach a specialized doctor and more 50 km to reach the regional capital Amiens to see hyper-specialists. On the left side are all the medico-social establishments with at least nurses and most of the time general practitioners. If these establishments incorporate telehealth station and medical networks are created, the equity will grow up considerably.

4.2 Research design

In order to develop the model, most of the data were extracted from official reports of the French statistic agencies (INSEE, DREES). As our study begins in 2010 and ends in 2040, projections of demographical data were found in these documents. To compensate the absence of specific data about telehealth in official reports, ground research was conducted during 6 month on the Télégéria experimentation in Paris and in two hospitals in the Picardie region. A series of interviews was realized to collect the needed data.

Furthermore, as recent developments in System dynamics demonstrate the importance of involving the people in the problem definition, we use the following methodology:

1 Group brainstorming with doctors and healthcare managers for problem identification,

2 Quantitative and qualitative data collection from the literature (official report, bibliographical articles) and semi-structured interviews with patients, specialized doctors, nurses and healthcare managers,

3 Model conceptualization, computer model formulation, scenarios creation and simulation,

4 Feedback to the group and improvement of the model and scenarios.

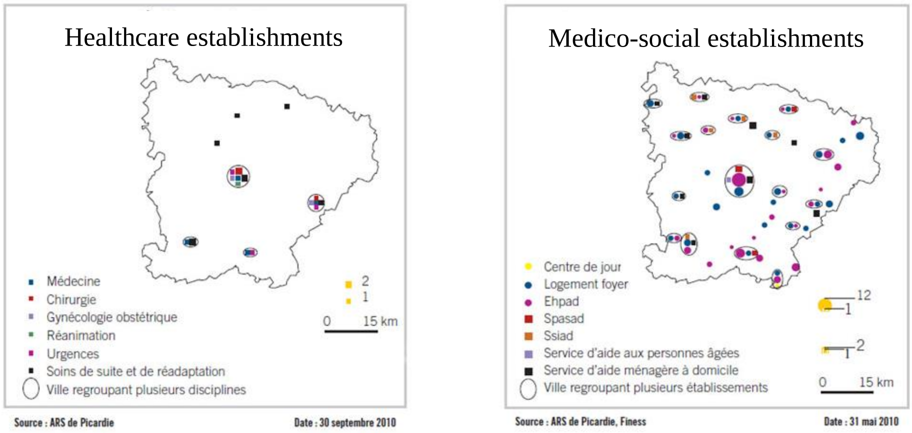


Figure 2: Establishment in the South-West of the Picardie Region (ARS Picardie, 2010)

4.3 First Step: Group Brainstorming and "action domains" specification

The first step of this method (group brainstorming) has underlined five main "action domains" that might have an influence on the budget and the equity indicators (these domains are presented in the five boxes of the figure 3):

1 Emergency department: telehealth will help to reduce inadequate recourse to the emergency department by providing a quick response to people that use this department to reach a doctor. It costs 1500€ for an admission versus 25€ for a consultation. The rate A corresponds to the percentage of emergency admission avoided;

2 Transport: by using telehealth, people are not transported. It costs 200€ as a medium price for a return to reach a hospital in the Picardie region. The rate B represents the percentage of consultation being done by telehealth if there is a station. A rate of 100% cannot be reached because specialties like gynecology cannot technically be done by telehealth until now;

3 Patient triage (such as prioritizing high-risk patients for earlier access): By using teleexpertise (like taking skin images for dermatology consideration), a sorting can be done to avoid inadequate orientation. Only the patient that really needs to see a specialized doctor will see it. It takes only few minutes (which is negligible in time in our model) for a teleexpertise versus 30 minutes for a consultation. The rate C characterizes the number of consultations that can be avoided by using teleexpertise;

4 Consultation duration: Doing a teleconsultation is much shorter than a consultation because of the better organization (same time with the patient, but less for administrative or travel time). The rate D corresponds to the percentage of time saved by doing a teleconsultation instead of a consultation. With the Télégéria experiment, we notice that it takes 0.4 hours for a consultation and 15% less for a teleconsultation;

5 Territorial equality: By implanting telehealth, people living less than 20 minutes from a station will be considered as a good distance for equity. In our model, the rate E is proportional to the overall usage rate of telehealth station implanted.

4.4 Second step: Data collection and exogenous variables specification

A rigorous data gathering has been made to collect the quantitative exogenous variables of the model. Most of the data were extracted from official reports. The two main ones are:

1. The number of specialized practitioners in the Picardie region. The DRESS (Directorate for Research, Studies, Evaluation and Statistics) (DREES 2009) reports that in 2010, 2000 specialized practitioners are present in this region and the agency predicts a decrease to reach 1800 in 2020 and then an increase to attain 2100 in 2040. This is partly due to the French numerous clausus (Langlois 2003);
2. As people aged more than 60 years old are the main target of telehealth, we use this demographic data. In fact, it is this category of population that lives in rural region, most of the time far from their children and dependent. The INSEE (*National Institute of Statistical and Economic Information)* (INSEE 2010) reports that, in the Picardie region, there are 380000 people aged more than 60 years old in 2010. The institute predicts that in 2040, they will be 600000.

The other variables as the different price of services (consultation price, emergency department price, and transport price), the number of consultation per year and per patient, and all time definitions where found by collecting data within one of the largest telehealth experiments, the Télégéria experiment, and in the literature.

4.5 Third and fourth step: Proposition of the simulation model for telehealth integration support

The figure 3 represents our final model conceptualization after feedbacks and improvement from the doctors and healthcare managers group.

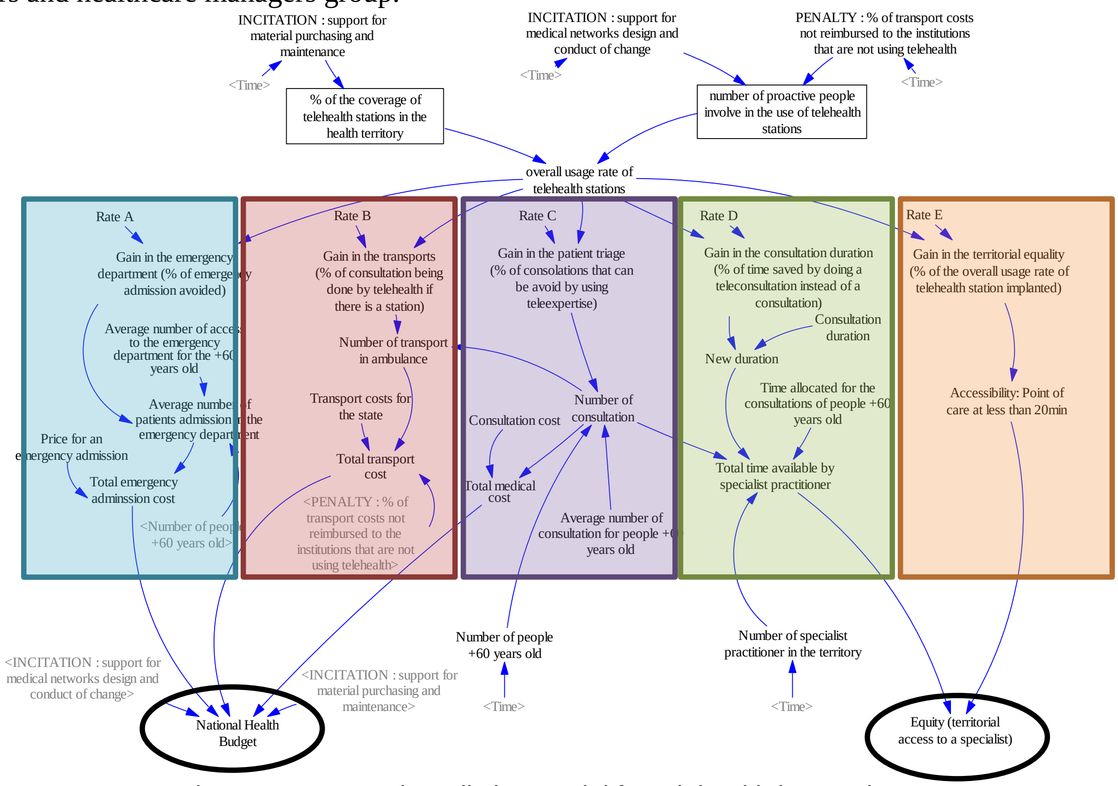


Figure 3: Proposed prediction model for telehealth integration

The five "action domains" are represented in the different boxes: emergency department, transport, patient triage, consultation duration, territorial equality. The two main inputs are outlined by the two arrows in the bottom of the figure: the specialized practitioners demography and number of people aged more than 60 years old. The three incitation and penalty variables described in the part 3 are at the top of the figure: support for material purchasing and maintenance, support for medical network design and change management; and penalty policies through a decrease in transport reimbursement for the establishments that are not using telehealth.

The different policies at the top of the figure have an influence on the coverage of telehealth station in the health territory and on the number of proactive people involved in the use of these stations. These two factors determine the overall usage rate of telehealth stations. The five main "action domains" use this rate to calculate the budget and the equity indicators. As telehealth is a complex system, the five categories are interrelated. For example, the average number of specialized consultations given per year and per patient has an influence on medical costs, but also on transportation costs and the total available time of specialized doctors.

5 RESULT AND ANALYSIS

The analysis results presented in this part respond to the two questions of section 3: *which scenario of overall usage rate is the best one to keep the budget and equity indicator satisfactory?* And *what are the main "action domains" where special efforts has to be made to influence the more the budget indicator?*

5.1 Overall usage rate of telehealth stations scenarios

In order to address this question, we made different scenarios of the percentage of the overall usage rate of telehealth stations (in percentage per year). Three of them are presented in this part: the scenario 0 without telehealth, scenario 2 and 3 with telehealth incorporation. These scenarios represent the low, medium and high integration scenarios. In the simulation, the different rates where specified as following: rate A = 5%, rate B = 50%, rate C = 15%, rate D = 15%, rate E proportional to the overall usage rate of telehealth station implanted. The different scenarios created can be compared as in Figure 4.

	Overall usage Rate of telehealth stations
Scenario 0	0% from 2010 and 2040
Scenario 1	0% from 2010 and 2015; a linear increase from 0% to 20% from 2015 and 2025; a linear increase from 20% to 30% from 2025 to 2040
Scenario 2	0% from 2010 and 2013; a linear increase from 0% to 40% from 2013 and 2025; a linear increase from 40% to 70% from 2025 to 2040

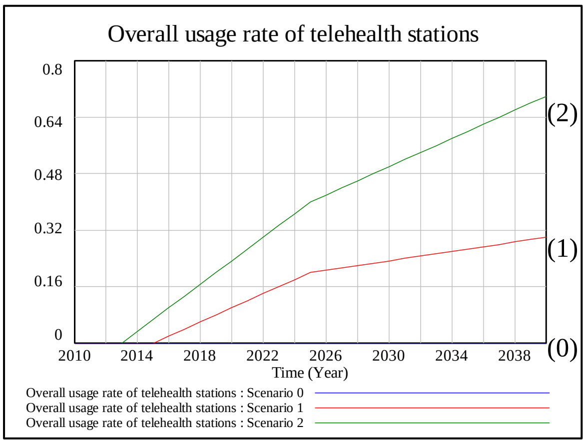


Figure 4 : Scenarios and their Overall usage Rate
Blue: Scenario 0, Red: Scenario 1, Green: Scenario 2

The impact of these scenarios on the percentage on the budget and the equity indicators are shown in figure 5.

This figure 5 shows that without telehealth, the healthcare budget continually increases from 280 M€/year to 440M€/year. But with the telehealth incorporation, in both scenarios, it increases, but much slower in the scenario 2 (which is almost constant at 290M€/year) than the scenario 1 (from 280M€/year to 370M€/year). For the equity indicator, without telehealth, time spent for people aged more than 60 years old will not be sufficient (represented by a negative value in the graphic). In the other side, the scenario 1 keeps this indicator very low but positive. The scenario 2 saves sufficient medical time during the entire time span to reach in 2040 the same value as in 2010.

In conclusion, these scenarios help choosing between different strategies for keeping the equity indicator positive or/and keeping the budget indicator constant. They indicate the overall usage rate that has to be reached each year to guide the importance and the efforts that have be done in the different policies presented in section 3.

5.2 Sensitivity of action domain

The objective of this question is to understand which domain is influencing the most the budget indicator. Monte Carlo simulations are an effective method to realize the sensitivity analysis. It involves isolating a number of variables, such as in this article, the rates A, B and C, and assigning them a probability distribution (a uniform distribution in this case). For each of these rates, a large number of random draws is performed to find the probability of the outcome, the budget indicator. The corresponding simulations on budget analysis are presented in figure 4.

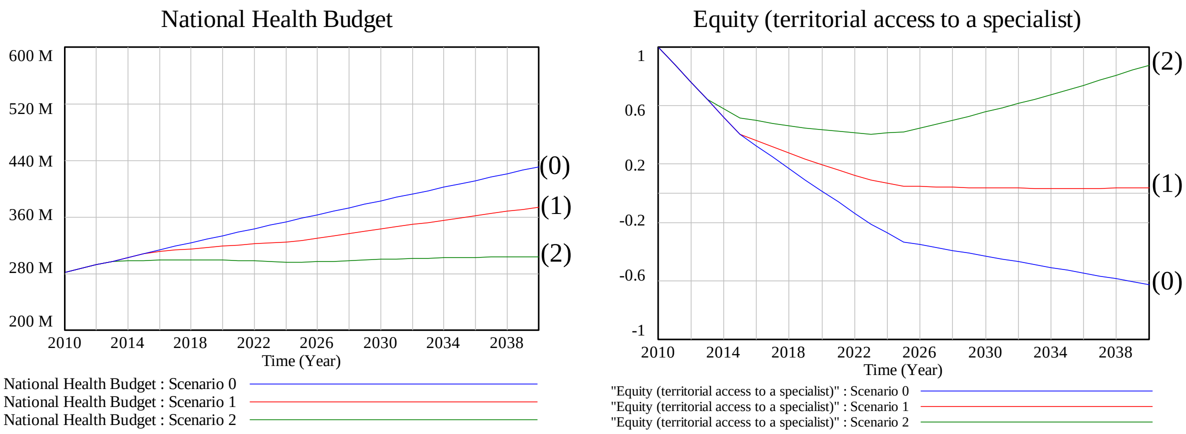
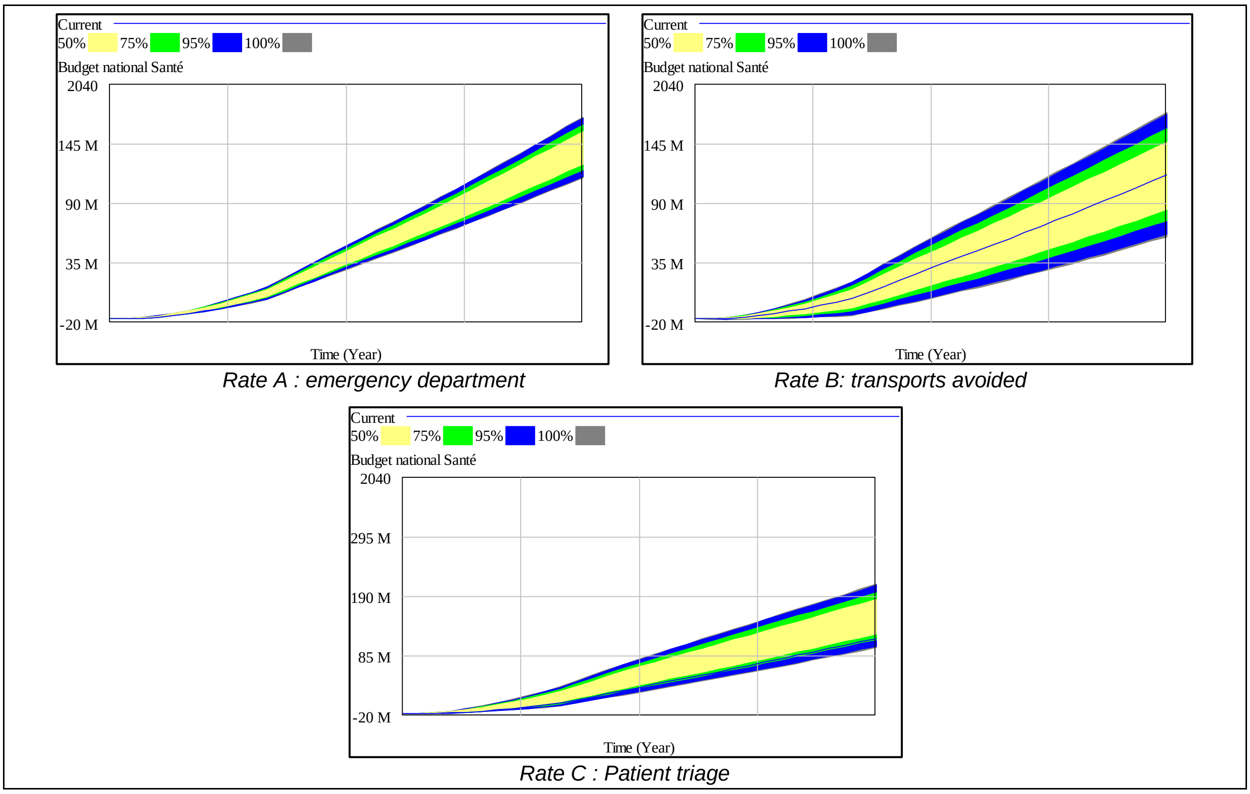


Figure 5: Left (budget indicator) and Right (equity indicator).
Blue: Scenario 0, Red: Scenario 1, Green: Scenario 2



Rate A : emergency department
Rate B: transports avoided
Rate C : Patient triage

Figure 6: Sensitivity analysis on the budget variable

This figure 6 shows that the transportation rate is the most influential for the system and special efforts has to be done in that field by taking decision to reinforce it. For example, by fixing a penalty that decrease the transport reimbursement for the establishments that are not using telehealth. The next most influential domain is the patient triage. It involves that works has to be made in the incorporation on teleexpertise in order to provide a better patient orientation.

6 CONCLUSIONS, GENERALIZATION AND FUTUR WORKS

System Dynamics is a rigorous modeling method coming from design thinking, that allows building formal computer simulations of complex systems and using them in the design of policies and more effective organizations. It was applied in various domains and in healthcare more recently. We use it to help for telehealth integration strategies. In this article, the scenario-based simulations of telehealth incorporation use the data of the Picardie Region. They take into account the number of telehealth stations and their effective use over time and provide decision support in order to reduce healthcare cost and save valuable medical time in this region. This model is generalizable for other regions in France, even in other countries. Further work on the relation between decision making and System

Dynamics tools will be done in this specific sector of healthcare but also in other types of problem concerning new technology integration in a complex system.

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