

Decision Support Systems in Health Care: towards a Simulated Health System

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Executive Summary

Computer-based decision support in health care with the application of simulation methods is receiving attention at European level as the indisputable advantages of these methods are getting widely recognized. Managerial and policy decision support however, have still to find their way into the forefront of the European developments. Relevant attempts remain fragmented and introvert, resulting in reportedly slow adoption rates by real practice.

This paper draws upon a framework of two interlinked practical cases, one from the private and one from the public sector, to portray its message. The first case follows a typical approach, where mainstream methodology and traditional implementation hinders the realization of a wider value proposition. The multidisciplinary collaborative approach of the second case responds to these identified limitations and is used to demonstrate the 'openness' of such tools and the array of potential results that can be achieved.

Inspired by the Virtual Physiological Human research objective, we extended this practical set of cases to a wider framework for collaborative and multidisciplinary multi-scale decision support. This framework aims to spark new directions in line with the EU ehealth agenda to better target and assist health authorities and managers.

The paper identifies lack of simulated-mass and simulation interconnectivity as a significant and underemphasized adoption barrier and recommends practitioners to turn to 'open' interoperable models as a mean to address the systemic complexity of high level decisions and to add sustainability to their work.



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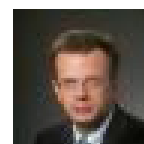
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“ Taking under consideration the complexity of executive decision making in the case that these systems were to be used, one could not help but wonder on how these decisions are currently being taken, when such systems are largely ignored. ”

1 Introduction

Information and communication technologies in health (also referred to as eHealth) are receiving reasonable attention, as their beneficial impact in the quality, access and efficacy of healthcare is getting widely recognized. The need to increase the adoption of these systems is well established both in the European and the US health agenda, as the health industry is growing more and more knowledge intensive. Medical practice is steadily embracing innovative ICTs to enable better cures and better means for early detection of diseases, although some scepticism exists about whether this process could be faster. Cutting edge European eHealth research has led to significant technological achievements, covering a wide range of health services, which have nevertheless failed to reach sufficient deployment in real practice. The adoption rate of technologies that focus on better practice management and administrative needs is reportedly (Wickramasinghe & Geisler, 2007) slower than that of the other eHealth applications.

Current European research in eHealth focuses on three eHealth aspects: Personal health systems, patients' safety and the virtual physiological human. Computer-based modeling and simulation are largely applied in two of the three priorities, indicating the potential of these methods and the recognition they enjoy in supporting medical decision making. These methods, however, have a significant history of application in numerous decision support health cases, where the objective is of a managerial or policy nature. Decision support systems (DSS) have shown moderate potential (and systemic weaknesses) in solving managerial problems that highly correlate to those that the European eHealth agenda sets forth as highest priorities, yet are somehow treated as a future issue, with health related data quality to be considered a primary burden.

In this paper we build upon a set of two recent practical cases, developed successively, to stress both why and how we could change health care decision support. The first case is a typical simulation application for a private health center, member of a leading corporate group, which although technically successful, comes short in achieving a larger value effect. The second case, developed with the international collaboration of the Medical school of Aristotle University, the Skin Cancer Center of Charite Berlin and the Erasmus MC, Department of Public health, answers to the weaknesses of the first case. An overview of both studies is presented here to serve as a basis for an extended framework of a multidisciplinary DSS. The functionality and the main features of this wider framework are discussed along with the potential of this type of initiatives over its limitations and shortcomings.

This paper aims to:

- Provide a practical example of the limitations of traditional decision support.
- Provide a good example of real collaboration and good multidisciplinary DSS development to respond to these limitations.
- Present a basis for discussion on future collaborative tools with application on the crossroads of policy making, patient management and technology.
- Contribute to the European eHealth agenda by providing new knowledge to support health authorities and health managers and utilize eHealth evolution and potential for better health care planning.

2 Developments and challenges

The demand for health care services is on the rise, as the European population is ageing and constantly seeking better and more access to health. It is estimated (Braun et al, 2003) that in 40 years, 65-year-old Europeans will account for 40 % of the population. Ageing however is not the only determinant of demand increase, as modern lifestyle and the rising prevalence of diseases due to increased risk factors, further contribute to this demand boom. On the supply side, health care providers face scaling costs and competition over both customers and resources, while investment risks are growing and legal frameworks are getting tougher. The stress-equation that is shaping over the health system is reflected on the underlying challenge to provide the best health care under the limited budgetary conditions. The use of eHealth applications is believed to bring a beneficial impact on both sides of this systemic problem, but its adoption is so far slower than expected.

The European eHealth Agenda

According to the European eHealth agenda, health authorities and managers responsible for the proper organization and running of health systems are hindered by the limitations of today's paper based aggregation and data processing in facing the increased budgetary pressures against the rising patient expectations (An action plan for a European eHealth Area, 2004). These limitations however are placed within a data quality spectrum, which although is very likely to be correct, represents only part of the problem. Timely, directly comparable data and infrastructure for collaboration are believed to empower health authorities to manage public health. The eHealth agenda further stresses the need for information processing in dealing with the complexities of health related information and knowledge without, however, realizing in full the implicated difficulties.

Supporting decisions

Providing the right data to health stakeholders is undoubtedly a big challenge. It is also undisputed that eHealth has contributed to the collection and storage of health information that is vital for a knowledge-based domain -such as health care- to thrive. Aggregation and analysis of these data into meaningful information is however, still lagging in progress as we move from database management to model-based management technologies (Tan, 1998 and 2005). Decision support and data utilization are falling short of our expectations, not only because of incomplete or non-comparable data but also due to the lack of a systemic multi-disciplinary approach to their analysis. DSS are not widespread (Kuljis et al, 2007) and usually fragmented to the extent of a single model or specific solution, with little re-usability or extensibility.

It is our belief that eHealth will in time be able to provide data as it is described within the agenda, but even then we will still be in need of efficient methods to be able to utilize them. Health stakeholders are facing ever-rising decision complexity with stale tools. The truth is that there is only scarce and fragmented effort to point out and work through this particular problem. Such foresight research could fasten the eHealth uptake and shed some light on what exactly we need to be collecting and how.

3 Decision support systems in health care

DSS supply managers with information and they propose solutions in semi- or unstructured decision-processes. DSS consist typically of repositories for data (i.e., databases or data warehouse), methods and models as well as sequence control systems. Health Decision Support Systems (HDSS) have been following the developments of mainstream information processing with a small time gap. From the

isolated diagnostic systems for research and training and the pioneering clinical decision support tools of the mid 50's to the clinical and administrative integration systems of the 70's to the 5th generation formal model technologies such as fuzzy logic Neural Networks and Graphical User Interfaces, HDSS has been widely applied to the health sector (for a more detailed reading in HDSS historical development see Tan, 1998).

Long application history, short success track

In this paper the method proposed and used is simulation modelling. Simulation has been used for modelling health care systems for over forty years. Health system simulation, simply put, is the application of modelling and computer simulation methods to study the interactions between individuals and/or components of a system and how these interactions over time produce the behaviour observed in the healthcare system (Lyll et al, 2008). Simulation has been applied to a number of health care areas (Homer & Hirsch, 2006), as can be seen in the table below. For a solid and consolidated reading on simulation applications in health care, a non technical reader can consult Fone (2003).

Application Areas in Health Care
<ul style="list-style-type: none"> • Disease epidemiology: heart disease, diabetes, HIV/AIDS, cervical cancer, chlamydia infection, dengue fever, and drug resistant pneumococcal infections • Substance abuse epidemiology: heroin addiction, cocaine prevalence, and tobacco reduction • Patient flows in emergency and extended care • Health care capacity and delivery in areas such as population health planning, dental care, and mental health, as well as how the health system will be able to cope with natural disasters and terrorist acts • Interactions between health care or public health capacity and disease epidemiology (Hirsch G, 2004 and 2005, Homer J, 2005) • Performance management • Evaluation of the performance and impact of information and communications technology applications on health care (Anderson, 2002), including Computerised Physician Order Entry systems and electronic prescribing systems designed to reduce medical errors leading at adverse events.

Table 1 Simulation applications in health care

Despite the long history of application and the wide range of areas it covers, simulation is not widely used in practice. Indeed, simulation is in many respects the ideal approach for addressing healthcare issues, yet the relatively small number of successful implementations suggests that it has been underused in the health sector (Brailsford, 2007). The gap between “suppliers” and “customers” is rather big, and in a sense demand never met supply. Simulation experts are failing to understand customer’s perceptions (Robinson & Pidd, 1998) and are still pretty much trapped in an obsolete “manufacturing” approach.

It is clear that simulation practitioners need to put new practical and innovative ideas on the table, try out new multidisciplinary and “open” models to combat fragmentation, and pay attention to their after-sales efforts to better support their results. The need for interoperable simulation modelling is surfacing, as stakeholders begin to realise the systemic inter-connection of the health system. It is on these identified gaps that this paper aims to contribute by adding a new perspective through the two-case framework presented in the rest of the paper.

4 The Corporate Health Group Case

This first case can be characterized as a typical simulation application in health care. By typical we mean the business-as-usual approach that is largely followed by decision support studies with simulation. Mainstream methodology is applied in a project-oriented attempt to enhance managerial decision making, and the main results as well as post-project findings are outlined here, to help showcase the limitations of the overall approach and to prepare the ground rationale of the second case.

4.1 Scope and methodology

The subject of the case study is a health center, member of a leading corporate health group, in the process of relocating to a more strategic location. The health center has been operating successfully for many years, and enjoyed a good reputation and stable growth. Under this opportunity, management decided to launch a simulation project to assess the old status, and project the current model to the future structure of the center, just before final arrangements were to take place at the new facility. The center's management is particularly interested in addressing three issues:

- Current status assessment (in terms of resource utilization, quality of service).
- Modeling of the new center and performance assessment.
- Performance test in situations of increased service demand.

Corporate management, however, is overly interested in a tool to assist its decision-making at operational level. Management reports, resource lists, and financial results are not adequate to facilitate precise and effective decision-making on higher levels of management, yet they are still considered the main tool for operational analysis.

Overview of Methodology

The methodology implemented in this study was based on commonly accepted Discrete Event Simulation methodology (Banks et al, 2004). An action plan was designed to break down work, to assign the work among the study team and to time-schedule the project. Below are the main methodological steps that were followed:

- Problem formulation and study plan
- Requirements specification
- Data collection Model definition
- Draft basic model and pilot run
- Basic model modifications and validation
- Design of the new center model, validation and acceptance
- Experimentation (What-if scenarios)
- Results (Performance assessment / comparative analysis)
- Suggestions/conclusions, management report

4.2 Implementation and results

Implementation was carried out by a single team of simulation modellers and was completed with the involvement of the centre's management in most of its development phases. Two main conceptual models were developed and tested for a number of validation tests. Data was primarily fed by the centre's ERP system and the operational manager's expert opinion. Computer modelling was assisted by a commercial simulation solution. The figure below illustrates a part of the conceptual model used in the simulation.

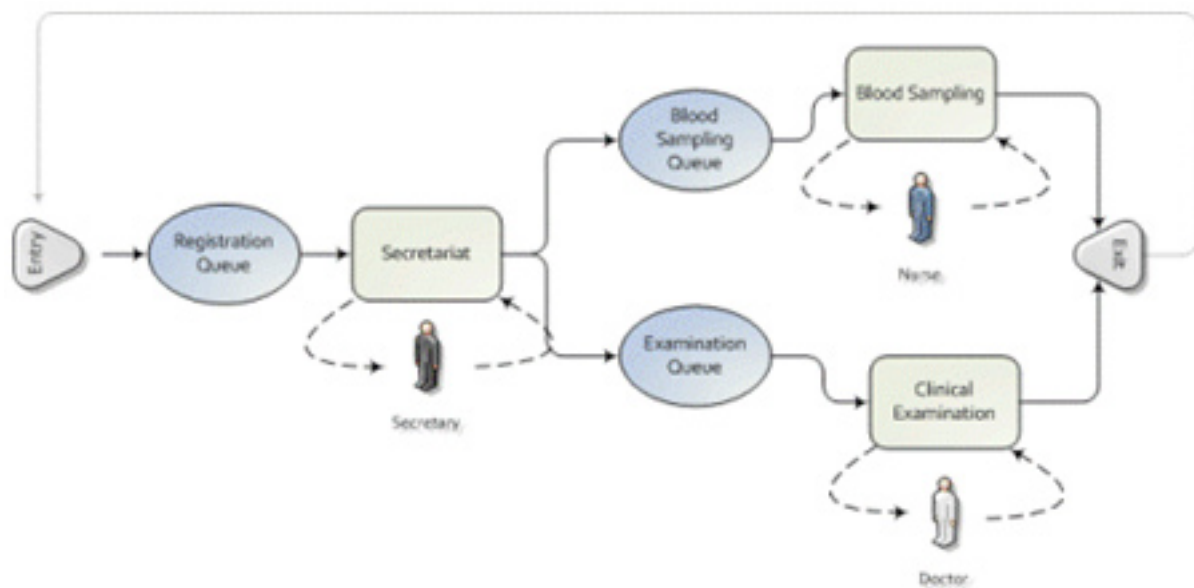


Figure 1: Snapshot of "Floor Two" conceptual model

Three main experimentation scenarios were elaborated with the respective results grouped under each. The experimentation results provided support in:

- Assessing the old center format and provide meaningful analysis of the workflow and resources, that checked with the knowledge and understanding of the manager.
- Formulating the new format out of the old and identify key implications of the layout change. Detailed workload balance analysis and recommendations were given.
- Anticipating repercussions of a given future demand rise in the new setting and a potential reduction in staffing.

4.3 Project implications

The results were presented to the centre's management and they were accepted as rational, credible and very helpful. The company implemented the study's main suggestion and did not reduce its staff. One year after the launch of the new center the manager was asked to verify and assess the impact of the results and recommendations that were given to him. The new center was launched with remarkable success and its management enjoyed a staggering increase in demand for its services. This resulted in a "bloom" in the center, which added a series of new services, and numerous new personnel to service the growing demand. All these "unexpected" changes made most of the

simulation recommendations obsolete, greatly reducing the study's impact.

This post-project assessment reveals a series of serious limitations to this typical approach that are shared by similar cases. The poor predictions, which provided the basis for experimentation and rendered the whole study irrelevant, should not be viewed as bad methodology, but rather as a lack of a multidisciplinary focus on implementation. The discontinuation of post-project support and the limited time scale, for which the study was intended, further limited the opportunity to add value through a more service oriented approach. The lack of openness or connectivity or a post-utilization plan drastically limited the post-project value, and all the work effort encapsulated within the model remained largely unutilized. Consequently the possibility that the group further adopts such methods is and will remain fairly small.

5 The Skin Cancer Center Charite Case

In this chapter a real case of particular interest is presented: an international multidisciplinary consortium collaborates to design a tool to assist in the strategic decision making. Traditional epidemiological modelling is combined with discrete event simulation for empowered experimentation. The objective of this chapter is to use this case outline as an (good) example, upon which a wider framework will be built in the next chapter.

5.1 Scope and methodology

Based on the identified weaknesses presented earlier in the first case and within the already established collaboration among the Skin Cancer Center of Charite Berlin (SCCC), the Aristotle University Medical school and the Public Health department of Erasmus Rotterdam, a research plan was created to guide the actions aiming to design a decision support method/tool to facilitate strategic planning and short-term capacity assessment. The physical simulation objective was the SCCC and the final tool user is SCCC executive management.

The initial objectives set early in the plan included the following:

- Develop a tool that applies forecasting methods to predict long-term demand changes and simulation to test if these changes can be serviced by the current infrastructure. If these changes cannot be supported, pinpoint the pressure points and produce strategic planning recommendations.
- Assess the current SCCC 'system' and recommend potential improvements.
- Provide Charite management with a powerful tool to:
 - assess their capacity, resource utilization, and Customer service and,
 - experiment with what-if scenarios and get strong response results.

A new methodological approach

The methodology deployed to reach these objectives was divided in two components, 'forecast' and 'simulation'. The first component is devoted on the management of the development of the epidemiological part of the study that aims to predict future demand for skin cancers.

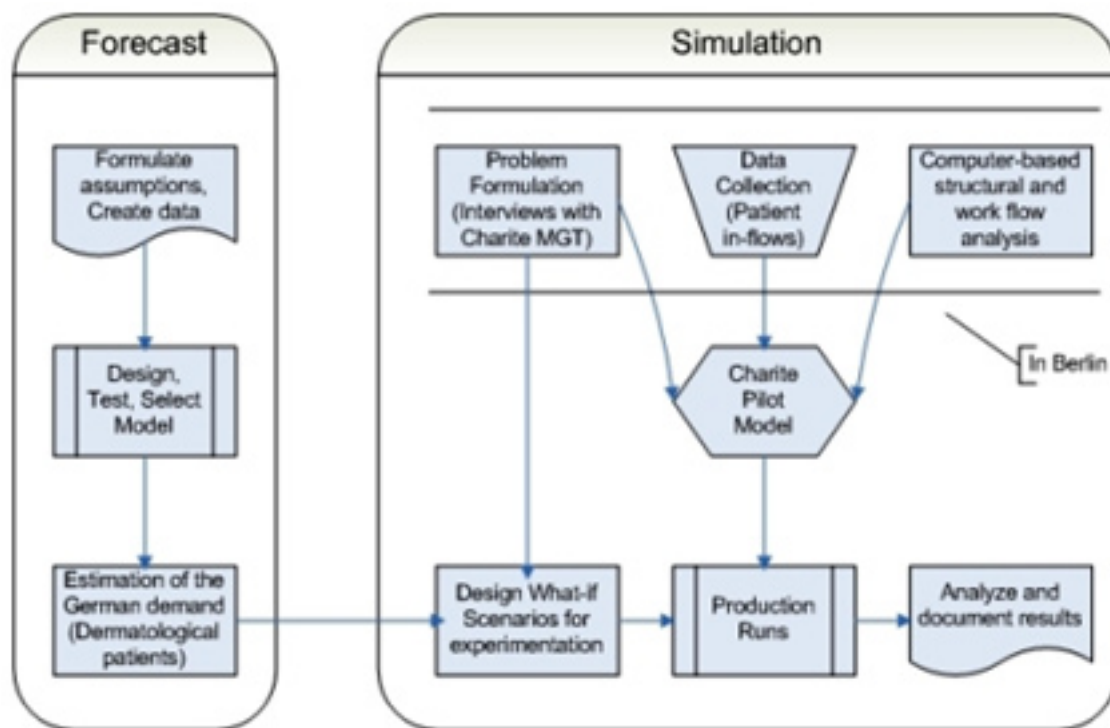


Figure 2 Methodology of the research plan

In the second component, a typical DES methodology is followed and executed in three levels - Data collection, modeling and experimentation. As can be seen in the figure above, component 1 feeds the experimentation scenario design module of component 2.

In this scheme, using the predicted number of incidents on the basis of population projections and risk factors, we design a specific experimentation scenario: what if the current center had to deal with the future (10 years horizon) demand? Then with the simulation model, we test that scenario and assess the center performance and move on to corrective actions. After this experimentation, the results are validated and analyzed to provide meaningful recommendations.

5.2 Implementation and overview of the results

The project was developed according to the above methodology. The forecast was based on Berlin population projections for 2018 and Dutch skin cancer incidents as collected by two cancer registries. With the use of simulation software the actual SCCC was modeled and the experimentation scenario was used to assess the center's capacity in increased demand. Below is a figure of the SCCC activity diagram used in the simulation.

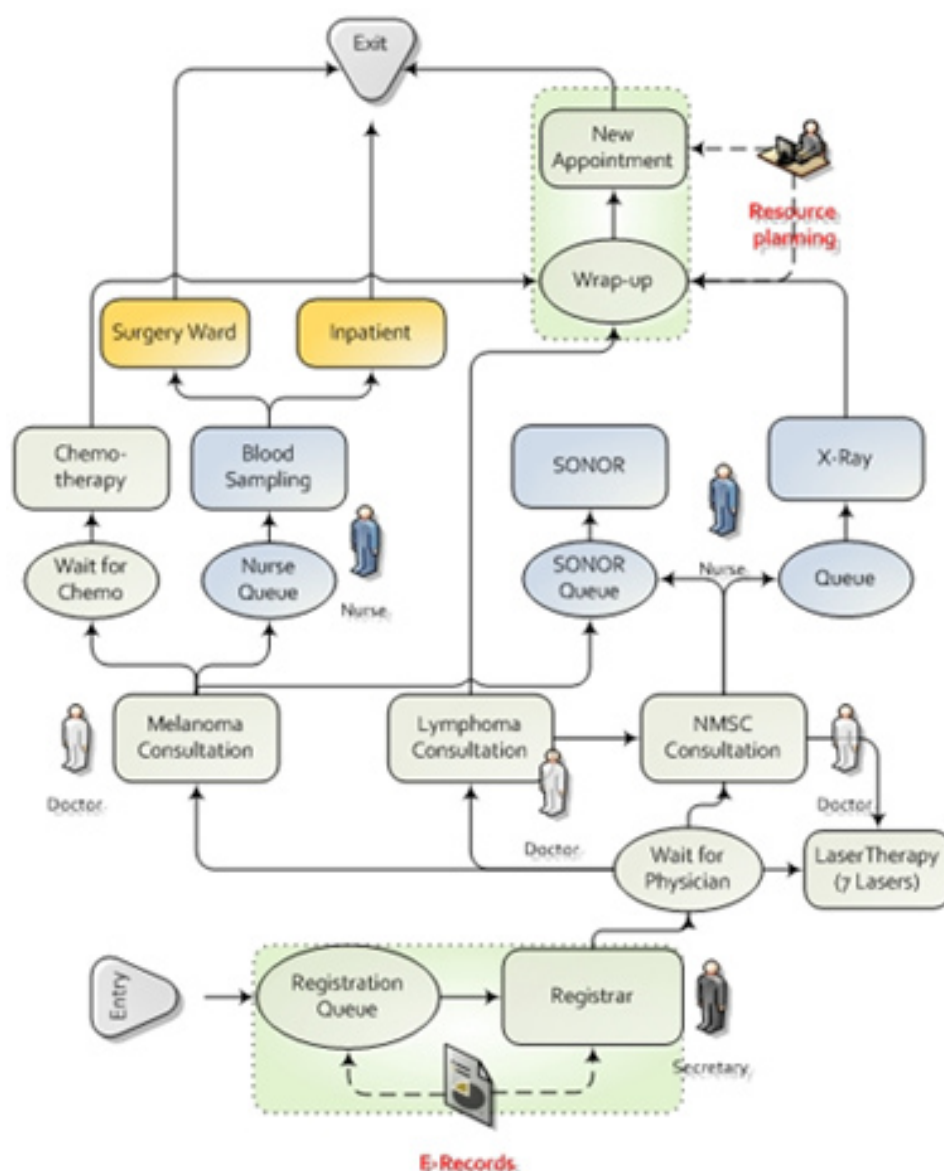


Figure 3 The SCCC cycle diagram

The project implementation was successful in:

- Assessing the current quality of customer service (in waiting times, time in system), resource utilization (percentage of working vs. idle) and identifying potential bottlenecks and corrective action.
- Assessing the ability to service the increasing demand without decreasing the current quality of service (as reflected by time physician allocates to patient) and identifying the human resource needs in a 10 years time-frame to meet these conditions (increased demand under the same quality).
- Presenting an open model for reuse of the SCCC layout. SCCC is considered a rather unique skin cancer center in European dermatology, and it is important that its model is open for anyone to get insights on its operation.

5.3 Post project utilization

The project is considered complete in meeting the initial objectives, although, as we were taught by the first case, there should always be a safe time before a study of this kind can be considered successful. One of the most important achievements remains the fact that this tool, if maintained updated, will be able to feed on identified changes in skin cancer prevalence to always be proactive in assessing and addressing the impact of these changes on the center's operational performance. Connecting epidemiology to operational management, however, is only a part of the bigger picture. The conceptual framework as presented here could be a receptor of more horizontal 'add-ons' like innovation diffusion models to include the technology evolution effects.

Empowering assessment

In addition to the use of the tool as intended in the original research plan, the tool can be flexibly used to assess numerous other possibilities. The model architecture is open to meta-analysis and experimentation on practically anything that has something to do or can be linked to either epidemiology or operational function. Interventions that aim to improve the operational performance by simplifying or facilitating administrative procedures could be easily assessed by the tool that is already developed. Inspired by two good European eHealth practices (RPS2 -Resource Planning System, and FLOW- national health care network), for instance, we could easily answer questions as to what would happen if the SCCC management would adopt similar solutions, or better put, what the operational impact of such an intervention would be.

In Figure 3 we isolated and indicated (with light green) the area of operational impact that would be affected by the implementation of an appointment facilitation system (like RPS2) and an E-record system. These systems will have a real impact on actual performance time for managing the patient records (at the moment they are hard-copy files) and they would probably diminish the time taken to schedule new appointments and manage all the follow-ups. The organisational changes that these interventions will assert are possible to model and concrete performance results can be obtained to support a decision about whether this investment will have a significant impact operationally.

The added value to the approach of this method is in the dynamic and analytic nature of the results it provides. Mainstream operational impact assessment is most of the times limited to a simplistic static numerical estimation of effect (e.g. percentage of decrease in administration time needed per file, aggregated to the number of files and average time of files processed). This method however simply gives a static preface of the ramifications of effects this might have in a system of thousands of interactions.

6 Towards a simulated Health System

The two cases presented above have shown how a logical reparative progression can lead us to new ideas to understand and exploit the value map. So far we have been able to connect epidemiology as a forecasting method to simulation modelling as an operational performance assessment tool, and we also provided a theoretical extension example with two interventions of administrative nature. Epidemiology, however, uses risk factors and historical data to forecast future incidents. Many public health interventions aim directly to the improvement (lowering) of risk factors that are causing disease. A health programme aiming to lower specific risk factors will result in fewer incidents (at least less than those that would have been expected without this action) and our model would be able to assess the operational impact that this programme will have. For instance, a promotional campaign about the dangers of sun exposure aiming to reduce skin cancer could well be assessed

beforehand on what impact this intervention would have on an operational level, in addition to its social impact.

Widening the framework

The ambition of this paper is to present a wider framework of decision support and include policy making for the whole health system (local, national or European). The biggest motive and challenge in widening the 'SCCC case' framework is creating critical 'mass'. The health system is a very complex set of heavily interconnected subsystems that altogether operate as a whole, and an intervention in one small part will have an effect on other parts as well. The biggest problem with simulation is exactly this; it is scattered, unconnected, and most of the times abandoned soon after the first results were made public.

In this manner, even successful simulation cases usually model a very specific area, which represents a tiny fraction of a small health subsystem. The SCCC case for example is good for in-house recommendations, but its scope is extremely limited to that of a clinic in a dermatology hospital in Berlin. And if we just think outside Berlin, or the skin cancer treatment, or even the hospital point of view, we will need to have much more of a simulated reality to model and address policy decisions. The same is true for corporate level decisions in the context of the health group and its operational network of 40 business units.

Ambition and inspiration

It is clear that the complication of a project simulating, a health system (or a subsystem) would be very costly to implement centrally. The perception of the difficulty of interconnectivity runs so deep that some experts have come to consider it unrealistic (Salt, 2008). Inspired, however, from the impressive Virtual Physiological Human research objective (translate all functions of the human body into a coherent set of multiscale computer models), where the emphasis is given on the integration of existing models rather than on development of new models (ICT Work Programme 2009-10), we propose to share the same view for the simulated health system.

The level to which integration in simulation modeling is possible practically dictates the percentage and scale-depth of the health system we could actually model. If local simulation models of physical or electronic health systems are to interoperate, mass could be built, and a central system could provide a test-bed for large effect analyses down the interactions chain. It seems more feasible to develop, maintain and update such local systems and try to connect them, than actually design and support a huge health system simulator. Once such a multi-scale integration is achieved, we could well support policy makers in assessing managerial aspects. Adding more multidisciplinary simulation objects will allow combinational decision support (clinical and operational). The above framework is presented in the figure below.

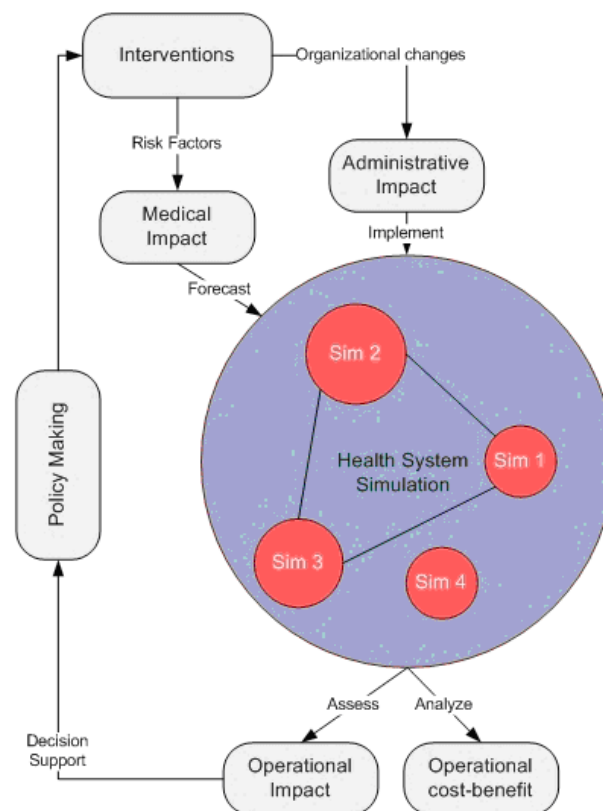


Figure 4 The extended health system simulation network

The figure above contains the essence of the methodology that has been developed for the SCCC case. In reality however, it is very difficult with our current knowledge to assess the feasibility of the proposed framework for a number of reasons since we lack the knowledge of how many simulation tools are operable at the moment; there is very little research on simulation modelling interoperability, and ‘translating’ the medical impact of intervention can be quite problematic due to poor epidemiological data management.

7 Conclusions - Lessons Learned

The framework presented in this study aims mainly to provide a new approach to health care management and policy making with the help of ICT tools and ideally spark some new collaborative efforts on the matter. As data collection is becoming comparable and more precise, we believe that these frameworks will not only become more feasible, but they will be part of the everyday decision support practice. The most promising finding so far is that simulation modelling is quite flexible and open to other disciplines and applications and can suitably serve as a basis for other components to connect on. Our team managed to identify limitations, to experiment with two disciplines, traditional epidemiology and simulation modelling, and come up with an open prototype tool that can be further developed.

We strongly believe that Europe is not utilizing the potential of such eHealth tools, and as a result its health sector is slow in innovation adoption as decision making is rather weak and consequently risk-averse. Decision support in health management and policy making is currently not a priority for the European Union and research is too fragmented to achieve significant penetration into real practice. Regardless of funding and prioritizing this type of methods, we learned that perhaps the most vital

element for successful development is collaborative work. It is therefore important for health researchers to focus on 'open' interoperable models rather than introvert one-shot projects.

Taking into consideration the complexity of executive decision making in the case that these systems were to be used, one could not help but wonder on how these decisions are currently being taken, when such systems are largely ignored.

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