Organizing networks of health care services:
A discrete event simulation model to analyse the interface between primary and hospital care services, with application to the *Setúbal* health care subregion

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Abstract — Governments in National Health Service (NHS) based countries have been concerned with how to organize services so as to achieve improvements in efficiency and quality in health care delivery, as well as to control costs. In this study, a stochastic discrete event simulation model to study the organization of primary and secondary care services, with reference to the context of the Portuguese NHS, is proposed. Both the conceptual model and its implementation in the Simul8 software program are described. The model was applied to the *Setúbal* administrative health sub-region, and for that purpose a database with 2005 production, resource and cost indicators was built to calibrate and validate the applied model. After validation, three different scenarios were tested: the first one concerning a 10% increase in demand, the second a shift between specialists and generalist physicians (changing the NHS focus from secondary to primary care) and finally a third one regarding a primary care restructuration. Results show that although the current system is not prepared to cope with a raise in demand, the other policy scenarios indicate that there is room to increase the system's efficiency and accessibility, while lowering the total costs from running the network.

Keywords — health system, discrete event simulation, referral network, primary and secondary care

I. Introduction

Most health systems have been under pressure to contain the increase in their costs, while simultaneously improving quality, efficiency and equity within the system. In order to achieve these objectives, it is essential to develop tools capable of helping public planners in NHS based countries, by providing information about the way systems are operating and about the impact of changes in the system.

A stochastic discrete event simulation (DES) model to study the organization of primary and secondary care services, and how those services interact, was developed. DES is a modeling approach useful to model operating systems and to deal with the stochastic nature of some variables, such as demand. Although it is uncommon to use this type of models at a macro level, its flexibility in the modeling of the interactions between the different services and providers, its flexibility for capturing stochastic elements, and the wide set of outputs that they provide, makes them a useful choice for modeling the considered problem (instead of using other commonly used optimization models based on mathematical programming). Given that the aim of this study was to test the impact of different scenarios on networks of providers, and also to consider a wide set of impacts on system indicators such as queues and waiting times to enter the different services (the system's response from the user's viewpoint), the level of resources used (which capture efficiency) and the cost associated with different scenario, we find DES models as a very useful modeling approach.

The structure of the present study is now described. In chapter II, the context and objectives of the study are presented, and in chapter III, a review of related literature is made. A conceptual model was developed and implemented to the Portuguese NHS (chapter IV). The model consisted on a representation of primary and secondary health care providers, on the services provided, on the existing referral networks between providers, and on the resources available. The conceptual model was then implemented using the Simul8 software. This implementation was made for a real case, the *Setúbal* health care subregion (SHCR), and involved the modeling of 21 Primary Care Centers (PCC) and 5 hospitals. Information from the year 2005 concerning production, resources and system costs was used to calibrate the model's parameters and to validate the model (chapter V). After the validation, three different scenarios were tested (chapter VI), regarding changes in the demand, a shift from secondary care to primary care resources, and closure of some primary care services.

II. Context and case study

This article aimed at studying the interaction between primary and secondary care in the context of an NHS. With regard to the Portuguese NHS, one of its key objectives is to "(…) *ensure the citizens equality in the accession to healthcare, regardless of their economic condition and their living place, and to ensure the equity of the resources use and distribution*" [1]. Yet, several problems have been referred to the system, like the excessive use of emergency services instead of primary care, the long waiting times for surgery and some outpatient consultations services, and the concentration of resources in hospital care and in urban areas. Moreover, there has been an increase in the overall system's cost [2]. Planners need to use methods to obtain information about how the networks of providers operate, as well as which is the expected impact of some policies and health care demand on the network of providers.

In NHS countries there are two main levels of care: primary care and hospital care. Primary care represents the first level of contact within the NHS, in the form of primary care centers (PCC). PCC act as gatekeepers, regulating the entrance in the system and the referral of users to upper levels. They have a generalist role, that should include

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disease treatment and its prevention besides health promotion, while following the users in their lifetime. From the services offered in this level, we consider that PCCs provide ambulatory care (which is provided for users by appointment), and emergency care services (AC and SAP), that do not need an appointment and can be provided by any physician working in the PCC (we define this as emergent care). PCC provides some other services that we do not take into account. We consider the PCC services classification used by IGIF [3].

On the other hand, secondary care is provided in hospitals, so it is more specialized and answers to situations that are mostly not treated in PCCs. Hospitals provide both ambulatory and inpatient care, with the hospitals being divided into 4 categories in the Portuguese NHS structure [4]: district hospital (DH), able to provide basic services; central hospitals (CH) that besides the basic services provide other more specialized services to wider populations; (highly) specialized hospitals (SH), not accessible for direct use; and level 1 hospitals (HN1), similar to DH but more focused in recovery and patients needing extended care. Hospitals provide three main types of services: emergency care, inpatient care and outpatient consultations.

Referral is the process of sending a patient from one service to other services inside the health system. Services tend to be organized into networks. For example, there are hospital referral networks (HRN), defined as *"systems that regulate the complementary relations and technical support between hospitals, to ensure the access of all patients to the services and healthcare providers"* [5]. Specific to each medical specialty, they try to articulate and connect all levels and services, exploring their complementarity while maximizing the resources' use, in order to ensure a rational and efficient use of the available resources. The referral process between primary and secondary care is of utmost importance, for it is the family physician at the PCC that makes the first assessment of the patient, and decides the best way to approach the problem(s). By doing so, decisions at the PCC level impact in the overall NHS costs (where care in hospitals tends to be more expensive) and in the secondary care workload. These aspects reinforce the need to study this specific type of referral [6].

This study presents a model that was applied to the SHCR as a case study. This administrative area was chosen for being an area that comprises two well defined subregions: the *Setúbal* Peninsula, urban and densely populated, with a growing young population; and the *Litoral Alentejano* region, rural and sparsely populated, with an aging and diminishing population. Overall, we have considered 21 PCC and 5 hospitals (1 CH, 2 DH and 2 L1H) –given its special characteristics, we have not considered a SH in the area.

The next figure presents the names and numbering of the PCCs and hospitals used in the case study, as well as the HRN used:

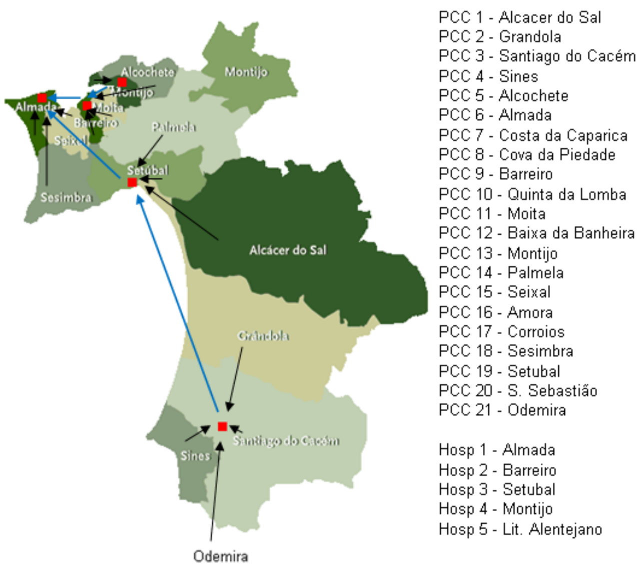

Figure 1: PCCs and Hospitals locations, and their referral areas (black arrows), with the emergency RRH represented with blue arrows. Their numbering is also represented (right column).

III. Literature review

Considering the problem at hand (on testing scenarios on networks of providers), there have been 3 main methodologies to approach it [7]: direct experimentation, mathematical programming models and simulation models. Direct experimentation consists in testing the hypothesis directly on the system, normally in a controlled way. Given that health care networks are a social experiment, these methods are costly, time demanding, and might produce results that might not be replicable to other context. Mathematical modeling models consist on representing systems by mathematical equations which capture the objectives of the system and the system's constraints. These models are good for obtaining optimal solutions but place difficulties in modeling dynamic systems, demand for simplifications and very often present problems in their global computations and demand the use of heuristic methods for their resolution, that sometimes lead to sub-optimal results. Finally, simulation methods are used for *"the imitation of the operation of a real-world process or system over time. Simulation involves the generation of an artificial history of the system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system that is represented"*[8]. Their main advantage is the huge flexibility they provide, both in modeling the interaction between elements of the system and the definition of parameters associated with them. This confers the model a great ease of experimentation, as it is simple to change the model or its inputs, allowing for testing different scenarios and hypothesis, in an easy, low cost, risk free and quick way.

Considering the objectives of this study, we have selected simulation as the most appropriate method to describe the users' progress during several events (referrals or the use of services for instance) while taking into consideration the stochastic nature of demand. In other words, a stochastic model is needed, based on events that occur at a discrete time. This type of simulation is known as discrete event simulation (DES), and has been used in several medical related areas, e.g. epidemiology, health promotion and prevention [9, 10], and the design [11, 12] and management [13, 14] of health care systems. Their contribution to the study of health related problems has been widely recognized [15]. Although simulation methods have been extensively used, they have been used mostly to analyse problems at the micro level, while analysis at a macro level has mostly used mathematical programming methods [16, 17]. Up to our knowledge, DES models have not been used to analyse referral networks at a macro level. Nevertheless, some studies on the Portuguese health system have somewhat analysed referral processes, either at the country [18] or regional and unit level [6,19,20]

Therefore this work differs from previous studies by proposing a DES methodology to study networks of primary and secondary care providers. The methodology might be seen as a decision support tool to help planners to decide upon referral and resourcing NHS policies.

IV. Developed Model

Considering the proposed objectives and context, the DES model developed had to take into account the demand for healthcare (and its stochastic nature), the location, size and resources used by providers, the HRN between the services and providers, and finally the associated costs. The developed model, both in its conceptual and implementation forms is now described.

A. Conceptual model

At first, it is necessary to define: the different levels and services –at a primary level, ambulatory care and emergency care (SAP and AC) and at the secondary level, emergency, inpatient care and outpatient consultation; and the movement of users between them.

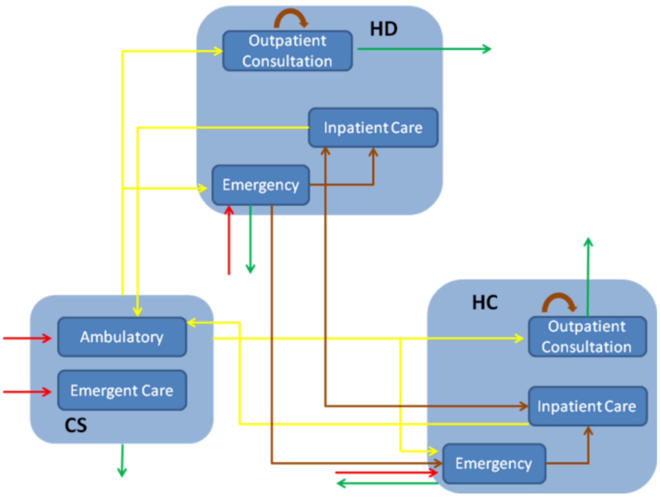

Figure 2: Schematic representation of the conceptual model.

In Fig. 2, the red arrows represent the direct entries of users in the system (in absolute demand values). These entries might be through PCCs (the system's gatekeepers), or through emergency services (secondary care level). From this point onwards, the user movements were determined in accordance with the referral networks used (and treated in a probabilistic way in accordance with past data). This means that the model uses information on the probability of a patient, after using one of the entry points, being sent home (leaving the model, green arrows), or being sent to another service. If the latter case occurs, we can make a distinction between a referral between providers (yellow arrows) or within secondary care providers (brow arrows). In the first case, the options are the referral of the user from the PCC to an emergency service; to an outpatient consultation; or from inpatient care to an appointment with the user's physician at the primary care level. In the second case (brown arrows), there might be inter-hospital (between inpatient care and emergency services) or intra-hospital referrals/transfers (inpatient directly after entrance in a hospital's emergency service or making a new appointment after an outpatient consultation, at the same hospital).

Analytically, the system is described as a set of variables and parameters that describe its behavior, as well as a set of equations that are required to define some relationships. To facilitate the presentation of the equations, each service is divided in three blocks: one concerning the users' entrance, a second one to describe the services use and a third one to describe to users destination.

Before presenting some key analytical relationships in the model, the notion of referral area must be defined. Referral area is the population served by a certain level of healthcare. Fig. 3 presents health care levels and their referral areas.

In this model the smallest area considered is the population served by a PCC. Although there are more divisions at a primary care level, they have not been considered in this study due to a lack of detailed information. In terms of secondary care, the CH, besides offering DH like services to population directly under its referral area, provides more specialized services to a wider population (considering the HRN in use, this population includes the users directly under their referral area, and the population served by DH not capable of providing the more specialized service in question).

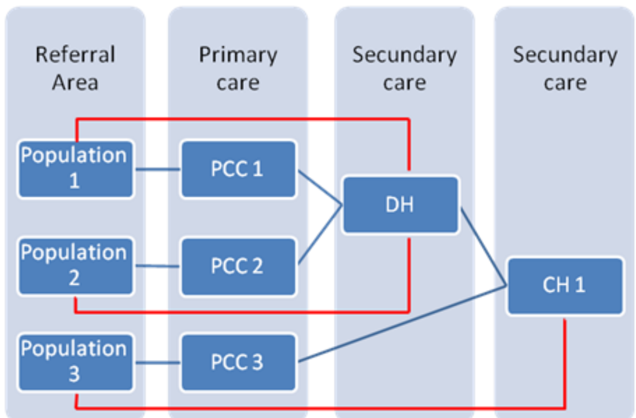

Figure 3: Relationship between providers and the populations in their referral areas. In red is the use of emergency services directly by the patient and in blue is the gatekeeping system for other cases.

The following description indicates all the variables (in bold) and equations that need to be calculated to each PCC and hospital, as well as some assumptions used in the model. For a matter of simplification, the indexes will be omitted from the equations, and the model takes into consideration the information commonly gathered by providers. Some remarks for the Portuguese application are indicated throughout the study.

1) Primary care

Entry

Exterior: Users enter in the system from the exterior, whether they have an appointment or are emergency cases. In a simulation model, this value is defined as the mean time between entrances (TBE, in minutes).

$$\mathbf{TBE\_PCC\_Amb} = \frac{\text{Schedule\_Amb}}{\text{N\_Consultations\_Amb}} \quad (1)$$

$$\mathbf{TBE\_PCC\_Emerg} = \frac{\text{Schedule\_Emerg}}{\text{N\_Consultations\_Emerg}} \quad (2)$$

Where: N_Consultations is the annual number of consultations of both types (ambulatory and emergent), while Schedule_Amb and Schedule_Urg is the total time (in minutes) during which the service is available to the users.

Users from inpatient care Patients after leaving inpatient care make an ambulatory appointment with their PCC physician.

Service

Number of physician This is a models' resource. It is important to know the average number of physicians in the PCC, for each service, during its working time. In order to do so, the total number of medical hours attributed to each service is divided by the number of hours it is open in a year.

$$\mathbf{N\_Physicians\_Amb} = \frac{\text{Hours\_Attributed \_Amb}}{\text{Schedule Amb}} \quad (3)$$

$$\mathbf{N\_Physicians\_Emerg} = \frac{\text{Hours\_Attributed \_Emerg}}{\text{Schedule \_Emerg}} \quad (4)$$

Duration of the Consultation: Average duration of the consultation, in minutes.

$$\mathbf{DC\_PCC\_Amb} = \frac{\text{Hours\_Attributed \_Amb}}{\text{N\_Consultation\_Amb}} \quad (5)$$

It is assumed that all the hours attributed to ambulatory care are spent treating patients. In the case of emergency consultations, due to a more sparse demand, we do not expect to physician to be occupied all the time. Thus, we use the variable **DC_PCC_Emerg**, is defined as half of the **DC_PCC_Amb** value.

Costs It is attributed to each user the total unitary cost (TUC) of the service.

$$\mathbf{TUC\_Amb} = \frac{\text{Cost\_Attributed\_Amb}}{\text{N\_Consultation\_Amb}}; \quad \mathbf{TUC\_Emerg} = \frac{\text{Cost\_Attributed\_Emerg}}{\text{N\_Consultation\_Emerg}} \quad (6,7)$$

Exit

Outpatient Consultation The probability (in % of entered users) of the user being sent to an outpatient consultation in the reference hospital is given by:

$$\mathbf{Prob\_PCC\_OC} = \frac{\text{New\_OC\_Hospital}}{\text{N\_Consultations\_PCC}} \quad (8)$$

Where New_OC_Hospital is the number of first outpatient consultations in a hospital/year; N_Consultations_PCC is the total number of consultations made in all the PCC belonging to a hospital referral area. This formula considers that all the new patients entered in an outpatient consultation service have been sent from a PCC, which is not totally true. Although it is a possible way to enter the service, there are others (like referrals from emergency services, intra-hospital references, direct entrances etc.) that are not taken into consideration, due to a lack of data.

Emergency: Probability of a user being sent to an emergency service in the reference hospital.

$$\mathbf{Prob\_PCC\_Emerg} = \frac{\text{Emerg\_Ep\_Coming\_PCC}}{\text{N\_Consultations\_CS}} \quad (9)$$

Where: Emerg_Ep_Coming_PCC is the number of emergency episodes resulting from referrals from the PCCs belonging to each hospitals referral area.

Home Represents the probability of the user being sent home after being seen at a PCC.

$$\mathbf{Prob\_PCC\_Home} = 1 - (\text{Prob\_PCC\_EC} + \text{Prob\_PCC\_Emerg}) \quad (10)$$

2) Secondary care

Emergency service

Entrance

Exterior Represents the users that enter in the service directly from the exterior.

$$\mathbf{TBE\_Emerg} = \frac{\text{Schedule\_Emergency}}{\text{N\_Ep\_Emergency}} \quad (11)$$

Where: N_Ep_Emergency is the annual number of emergency episodes in each hospital resulting from direct entrances (total number of episodes without referrals from other emergency services and users sent from PCCs). The schedule is the number of minutes in a year.

Primary Care: According to the value **Prob_PCC_Emerg**.

Transfers from other hospitals Represents the movement of users between emergency services. Given the difficulty in obtaining data for this parameter, in the case study the transfers were always to the hospital higher in the hierarchy (based on [5]).

The access to the emergency service is prioritized. It is considered that cases coming from the PCC's or other emergency services have a higher priority, as well as a certain percentage of the direct entrances from the exterior.

Service

Duration of the Consultation: Average duration of the consultation, in minutes (**DC_Emerg**). Given the difficulty to define this value, the simplest assumption is used, considering it equal to 20 min.

Number of physicians For each emergency service, the number of physicians is:

$$\mathbf{N\_Physicians\_Emerg} = \frac{\text{N\_Ep\_Emerg} \times \text{DC\_Emerg}}{\text{Schedule\_Emerg}} \quad (12)$$

Costs It is attributed to each user the total unitary cost (TUC_Emerg) of the service.

Exit

Inpatient Care: Probability of the user being sent to the inpatient care service of the same hospital. (N_Interned is the annual number of patients interned coming from the emergency service, for each hospital).

$$\textbf{Prob\_Emerg\_Inp} = \frac{N\_Interned}{N\_Ep\_Emergency} \quad (13)$$

Transfer Probability of the user being transferred, being N_Transf_Emerg the number of transfers from each hospital, from the Emergency service.

$$\textbf{Prob\_Emerg\_Transf} = \frac{N\_Tranf\_Emerg}{N\_Ep\_Emerg} \quad (14)$$

Home: Probability of the user being sent home.

$$\textbf{Prob\_Emerg\_Home} = 1 - (Prob\_Emerg\_Inp + Prob\_Emerg\_Transf) \quad (15)$$

Outpatient Consultation

Entry

PCC Sent from primary care, **Prob_PCC_OC**.

Service

Duration of Consultation Average duration, in minutes:

$$\textbf{DC\_OC} = \frac{Hours\_Attributed\_OC}{N\_Consultations\_OC} \quad (16)$$

Number of physicians Considering that this service's schedule, regardless of the hospital, tends to be 250 days a year, 6 hours a day, each hospital provides 1500 hours/physician every year (90000 minutes/year), we have:

$$\textbf{N\_Physicians\_OC} = \frac{N\_External\_Consultations \times DC\_OC}{90000} \quad (17)$$

Consultation cancellation: Percentage of consultations not realized due to the user or physician absent (**Cancellation_OC**). The user makes another appointment, as soon as possible, returning to the beginning of the queue.

Number consultations/user: Mean value of consultations per user, after the first one.

$$\textbf{N\_OC} = \frac{N\_Following\_OC}{N\_First\_OC} \quad (18)$$

Time between consultations: Average time between consultations, per user, where 525600 is the number of minutes in a year.

$$\textbf{Time\_Between\_OC} = \frac{525600}{N\_OC + 1} \quad (19)$$

Costs Attributed to each user is the total unitary cost (**TUC_OC**) of the service.

Exit

New Consultation While the user doesn't reach the total number of consultations planned, it makes another appointment after using the service.

Home After making the last planned consultation, the user leaves the system.

Inpatient Care

Entrance

Emergency According to **Prob_Emerg_Inp**

Other Entrances Number of entrances whose origin is not the hospital's emergency service.

$$\textbf{TBE\_Other\_Inp} = \frac{525600}{N\_Interned\_Not\_Emerg} \quad (20)$$

N_Interned_Not_Emerg is the number of internments not coming from the hospital's emergency service.

Service

Number of beds Represents the number of beds available at each hospital (**N_Beds_Hosp**).

Internment Duration Time the user spends using the service (**DC_Inp**).

Costs It is attributed to each user the total unitary cost (**TUC_Inp**) of the service.

Exit

Ambulatory consultation After leaving this service, the patient makes an appointment with his physician at the PCC, being then treated as a normal user by the model. Although the model considers that all the patients make this appointment (due to the lack of data), in reality this is not expected.

Transfers: Probability of the users being sent to another hospital.

$$\textbf{Prob\_Inp\_Transf} = \frac{N\_Transfered\_Inp}{N\_Interned} \quad (21)$$

N_Transfered_Inp is the annual value of patients transferred to other Inpatient Care service. This happens after the average internment duration.

B. Computational implementation

Before proceeding, it is important to describe the Simul8 main building blocks.

	Work Entry Point – WeP: Entry points for the entities or work items into the model
	Storage Bin – SB: Passive components, act as queue lines
	Work Center – WoC: Capable of collecting or receiving items, it changes and/or sends them to other elements in the model.
	Resource - Res: Act as constrains to the Woc, regulating their behavior.
	Work Exit Points – WeX: System's exit points

Table 1: Simul8 model building blocks.

The following description, describes the Simul8 implementation based in the Fig 4.

The PCC's entrance is modeled by a WeP (**A**), configured to act in a passive way, one WoC (**B**), which regulates the user's entry in the model according to the parameter **TBE_PCC_Amb,** and one Res (**C**) responsible for the schedule of the service. After their entrance, the users are sent to a queue, (**D**), represented by a SB, from where they leave to the consultation. The consultation is represented by a WoC (**E**), that pulls the items from the SB and processes them (here the parameters **DC_PCC_Amb** and **TUC_Amb** are used, and whose functioning is regulated by a resource (**F**), representing the number of physicians available (**N_Physicians_Amb**). Finally, this WoC redirects the user using the parameters **Prob_PCC_Emerg**, **Prob_PCC_EC** and **Prob_PCC_Home**), whether to the secondary care level, or to the service's WeX (**G**), from where he leaves the simulation. This description is identical to both services, ambulatory and emergent.

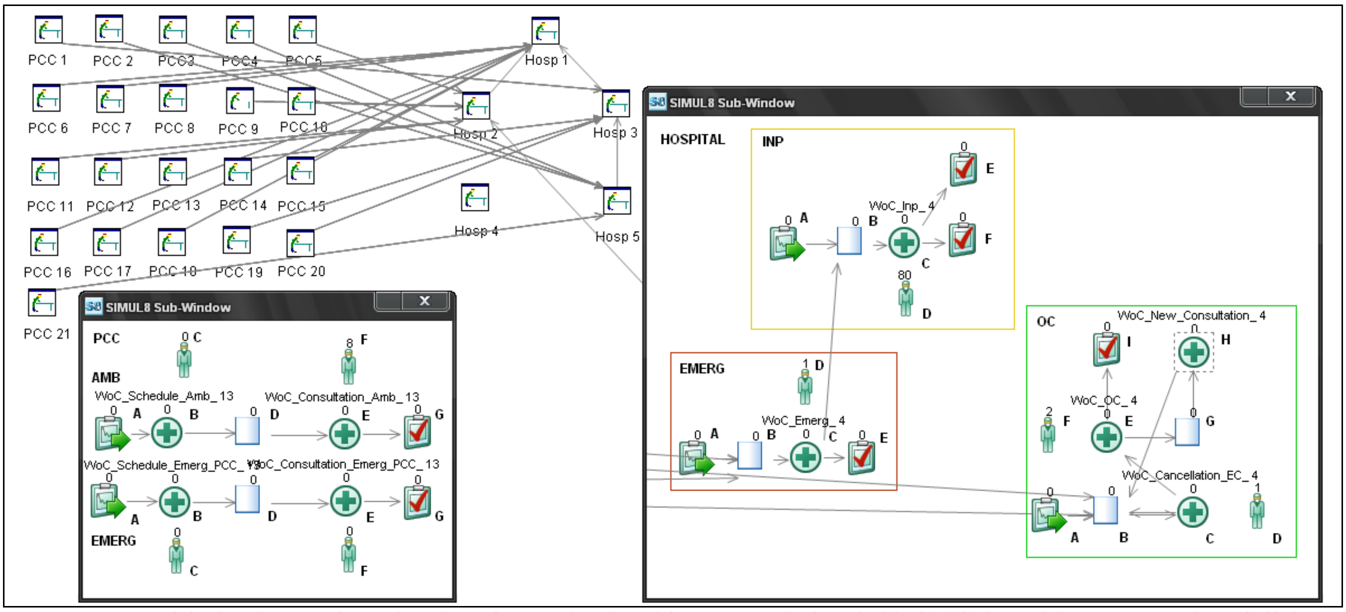

Figure 4: Model's implementation using the software Simul8, with a PCC and a hospital in highlight and the representation of all the interactions between the elements. 21 PCC and 5 hospitals were modeled.

For hospitals, the Emergency (EMERG) service is composed of a WeP (**A**), where it is defined the parameter **TBE_Emerg**, a prioritized queue (SB, **B**), that orders the users according to their status (emergent or not, defined by the label Emerg_Cases), one WoC (**C**) with the value **DC_Emerg** and a resource (**D**) that defines the number of physicians available (**N_physicians_Emerg**). Finally, the WeX (**E**) removes from the model the users sent home. The inpatient care service is very similar (INP), apart from the fact that the queue is not prioritized, and there are two exit points: one, **E**, is the exit point for the users sent to a consultation in a PCC, and the other, **F**, for the transferred users. Finally, the outpatient consultation service. Here the users (after leaving the WeP (**A**), or arriving from primary care), stay in a SB (**B**), until they are pulled by the WoC_Test (**C**, whose schedule is controlled by the resource **D**). This WoC "decides" whether the consultation takes place, according to the value **Cancellation_EC**. If the consultation is cancelled, the users return to the SB, where he makes another appointment. If not, they go to the WoC_EC (**E**) that works together with the resource N_Physician_EC (**F**). After the consultation, the user is sent to another SB (**G**), where he stays during the time between consultations (defined as the SB shelf-life). After this waiting, the users are pulled by the WoC (**H**) and sent to the first SB in order to make another appointment. After the total number of consultations defined (registered by the label N_EC), the user is sent to the WeX (**I**) and leaves the model.

Being a simulation model, the users entrance is regulated by the sampling of an exponential distribution, the distribution commonly associated in the modeling of occurrence times for independent events. This distribution is regulated by a single parameter λ, equal to 1/TBE, calculated for each entry point.

V. Data Collection and Validation

Simultaneous to implementing the model, data collection was made and the model's parameters were calculated. There were some difficulties associated with the data collection process, due to the existence of several sources with incomplete or contradictory information, or with data for which its collection process was not clear. These factors have created some doubts on the quality of some data, thus some awareness is needed when looking at it. The following tables present the sources used for calculation of parameters.

A. Data Collection

Primary Care	
Variable	**Parameter: [Source]**
TBE_PCC_Amb and TBE_PCC_Emerg	Number of minutes/year the service is opened: [21]
	Number of work days, weekends and holydays: [22]
	Number of consultations: [23]
N_Physicians_Amb/ Emerg	Hours_Attributed _Amb and Emerg: [23]
TUC_Amb/Emerg	Costs: [21]
Prob_PCC_Emerg	Users entered in hospitals coming from primary care [24]
	Total number of consultations in PCC: [23]
	Number of emergency episodes: [25]
Prob_PCC_Ext	Total number of outpatient consultations: [24, 26-28].
Secondary Care	
Variable	**Parameter: [Source]**
Emergency	
TBE_Emerg	Number of emergency episodes: [25]
Prioritization	Percentage of emergency cases: [29]
DC_Emerg e N_Physicians	No data was found
TUC_Emerg	Costs: [30]
Referral Values	Users destination: [25]
Inpatient Care	
TBE_Other_Inp	Users entered: [22]
	Users coming from the emergency service: [25]
N_Beds_Hosp and Internment Duration	Obtained directly from [25]
TUC_Emerg	Costs: [30]
Exit	Transfers: [31]
Outpatient Consultation	
DC_OC	The mean value for ambulatory care consultations was used
N_Physicians _OC	Number of outpatient consultations made: [24-28].

Cancellation _OC	Outpatient consultation cancellation percentage: [24]
N_Following_OC	Number of outpatient consultations made: [24-28].
CUT_OE	Costs: [30].

Table 2: Sources and parameters used for the calculation of the model's variables. In the patient care service, given the fact that each hospital receives and transfers patients to a large number of hospitals (most of them not included in the model), it was chosen to ignore the transfer of users between these services, and only the probability of a patient being transferred is calculated, regardless of their origin or destiny.

B. *Validation and calibration*

Validation of the models was constrained by production and cost values. A black-box approach was used, with model's output (number of consultations and referral values obtained) being compared with the information collected for the real system.

The model was run in an AMD Dual Core 3800+ with 3 Gigabytes of RAM, using the Simul8 13.0 and Excel 2007 software. The warm-up period was 630720 minutes (20% more than the longest event in the model. This assumption was made according to the [32] recommendation) and the data collection interval was 525600 minutes (one year, to coincide with the real data collected period). The results were obtained after trials of 5 runs, as 95% confidence intervals for the average value obtained as a result of the runs. These intervals were calculated according to the standard deviation of averages. Thus, increasing the runs per trial would result in a lower uncertainty associated with the result's average value. Nevertheless, due to the high computational burden associated with the model, only 5 runs / trials were run. Using 5 runs means, we have computed the 95% confidence interval for the results. Although a more powerful statistical analysis between the obtained values and the real ones could be used, that analysis was not carried out as this study is a preliminary study to test the exploratory DES methodology for analyzing networks of care. For validation purposes, we have checked whether the real values were within the confidence intervals obtained.

After running the model and under the assumption that there were no queues to access the services (due to a lack of queuing data), the results obtained were as expected –almost all real values were within the confidence intervals. A few corrections were made in order to validate the model (so no significant differences between real numbers and expected numbers were obtained): the number of available physicians was marginally changed for three hospitals and for one PCC so that all real numbers were within confidence intervals. This validated model was used to test the impact of some scenarios.

VI. TESTED SCENARIOS AND RESULTS

Several indicators were extracted from the simulation model. These included: queue mean sizes, number of entered users and number of users in the queue at the end of the simulation, average waiting time (and standard variation), the total number of consultations, resources use, the service total cost and, for primary care, the weight of emergency care in total primary care costs. For emergency services, the mean waiting time (and its standard deviation) were obtained for both cases, emergent or not, and the percentage of users with waiting times higher than 4 hours is also collected.

Analysis of results should bear in mind that there were no queues (waiting lists) to access the services. Results for the model representing the current situation (2005) show that: the use of medical resources for primary care is around 90% for the ambulatory service, being lower (20%-30% lower) for emergency care, due to its lower demand (as expected); for secundary care, the same resources use is between 90%-100% (this is expected as the model was calibrated with effective production data). Total costs are presented in Tab. 3. Concerning costs, the Garcia da Orta's weight in the secondary care should be noted, as well as the weight of the secundary care in the total cost of the system. This reinforces the ideia that the cost per user increases with the increase in the degree of healthcare specialization. We now describe each of the tested scenarios.

A. *Scenario I*

In the model it is assumed that there are no queues to enter the services. Considering that this hypothesis may be unrealistic, a scenario was tested assuming a 10% demand increase in all entry points from patients, keeping all the remaining parameters constant. This scenario serves to test the system response to increased demand, and also might be interpreted as: given aging population which will use more health care services, the existence of population not registered in the system (due to large increase of population in urban areas), and given waiting lists, it is expected that the demand for healthcare will increase in the future.

Results show that a 10% increase in demand would lead the current system to a rupture point where most resources are used at a 100% level. This happens to 12 of the PCCs, and to the emergency and outpatient consultation services of the majority of the hospitals, leading to the appearance of queues, to the increase of waiting times and to an overall increase of the system's total costs (Tab. 3). These results indicate that the current system (with its characteristics and efficiency levels) is not expected to cope in the future with current and future increased demand. Some of results on high utilization levels should be interpreted with caution given the data used to calibrate the model. More information would be needed to a more in-depth analysis of this scenario. In terms of costs, this scenario implies a substantial increase in the level of primary care costs, due to the direct pressure on the gatekeeping system.

B. *Scenario II*

Although there is no consensus regarding the best proportion between generalist and specialized physicians, it has been suggested that this value should around 50/50 [33, 34]. Portuguese 2005 official data [25] indicates that there are 8558 generalists working in the NHS, which represents 36,6% of the total number. Thus, although there is not a shortage of physicians in the system, their distribution between specialties is not the recommended by the literature.

Thus, scenario II considers a physicians' shift from secondary to primary care. Keeping the global number of physicians constant, the number of generalists (working in ambulatory care at the primary level) was raised by 20%, and the number of specialized physicians working at the outpatient consultation services was diminished by 11,5% (so as to keep the global number in the system constant). Considering that such a large change in the resources distribution would also imply a change in the demand patterns, it is expected a simultaneous increase for the demand of primary care services, and a lower demand for secondary care services. Consequently some other parameters were also changed: the demand for ambulatory care at the PCC was raised by 5%, and the referral rate from primary care to outpatient consultations was reduced by 20% (because this is the only entrance in the model for the outpatient consultation service, and it is expected that a better following of the user by a generalist physician would lead to a less demand at the secondary level). PCC's emergency services were kept without changes, and for the emergency service a 5% reduction was considered (given the larger ease in acceding to the primary care).

The results obtained for scenario II seem to be promising: even considering an increase in the demand for primary cares, the reinforcement of the number of physicians seems to allow for a better service, with the reduction of waiting time to enter the consultation service and resources' use (for values around 80% in the ambulatory care), guaranteeing this way a better system's capacity to cope with demand and a bigger efficiency of the same. The simultaneous assumption of the reduction for demand of secondary care services has shown that with a more efficient gatekeeping process, the waiting times and the size of the queue for outpatient consultations in hospitals drastically diminishes (reduction of 71% in the time of access and 75% in the size of the queue for the 3 bigger hospitals of the region). Simultaneously, there was an increase in the weight of the primary care in the cost's structure (more 2.26%), and a global saving of 7,19 million euros (less 1.47%). These savings result to a large extent from the service of outpatient consultation (savings of 11.79%).

The assumptions made in this scenario could therefore be a way to stimulate the access to primary care, reducing the search for the secondary care made possible by the gatekeeper role of general practitioners, while increasing the role of health promotion (versus treatment). In accordance with the expected, and confirmed by the model, it would be possible to provide a better service to the population, guaranteeing a bigger easiness of access to the system and a continued accompaniment of the user by its physician at primary care. The benefits (both in illness prevention and equity) of systems centered in the primary care have already been recognized in the literature [35]. Simultaneously, these measures would allow for savings since secondary care is normally more expensive than primary care, due to the biggest degree of specialization. Of course this scenario assumes some drastic changes which could only be possibly achieved in the long term, given that they demand also for shifts in medical education numbers by specialty, in resources' planning and in population's habits in the use of health care services.

C. Scenario III

In a time where several emergency services at the PCC's are being progressively shutdown, we tried to simulate the impact of this measure. In order to do so, 80% of the PCC's emergency services were closed; while 3 of them were kept open (these 3 were the ones with lower accessibility of local populations to hospital emergency services). Using data from googlemaps, the services which were not closed were *Alcácer do Sal*, *Grândola* and *Odemira* SAP's.

Parallel to the services shutdown, this process was compensated by the increasing of ambulatory care opening hours, so as to facilitate the access to these services. Some policy attempts towards that direction have already been tried in Portugal –that was the case of the 1998 experimental payment system (*Regime Remuneratório Experimental*, RRE) for general practitioners (Decree nº 117/98) which attempted to promote team work by physicians which would guarantee continuous and extended opening hours in some PCCs (which would lead to a different payment system). More recently, a new system has appeared to promote the creation of family health units (FHU) (conditions of this system available in the decree nº9/2006 [34] which are in some cases paid as in the RRE system (these are model B FHUs which constitute 33% of the total 64 FHUs).

Consequently, this scenario attempts to catch the effect of the shutting down small dimension emergency services, assuming that the transference of the resources is made in accordance with the FHU/RRE model. Thus, the resources used by the PCC's emergency services were transferred to the ambulatory service, together with the respective demand (demand decreased by 5% -an effect of direct substitution is not expected; a better accompaniment of patients by a general practitioner and an easier access to primary care should lead to a lower use of emergency services in non-emergent situations). Simultaneously, other parameters were changed: for the average consultation duration was computed as a weighed mean of the duration of the ambulatory and the emergent consultation, with the same being done to the consultation costs. Finally, taking into account the report available in the website of the mission for the primary care services regarding the impact of the FHU/RRE [34], the cost of each consultation is expected to decrease by 14,4% (scenario III a)). In scenario III b), we consider a more conservative where this additional cost reduction is not contemplated.
One of the consequences of this scenario would be the widening of the schedule of ambulatory care. We have chosen to model this by extending the daily ambulatory care opening hours by 30 minutes for all the PCC.

In summary, this scenario consists of: shutdown of most emergency services within PCCs; transferring those resources to PCC ambulatory service; transferring 95% of the demand from emergent to ambulatory service; changing the parameters of cost and duration of the consultation by a weighed mean between the ambulatory and emergency services being closed; and the introduction of some of the benefits of the FHU/RRE management model, by increasing the ambulatory care opening hours by 30 minutes and diminishing the consultation cost by 14,4%. This scenario represents a reorganization of primary care services through the elimination of services and transfer of resources to other services.

2005 values after calibration – Secondary Care							
Services/ Hospitals	**Garcia de Orta**	**Barreiro**	**Setúbal**	**Montijo**	**Litoral Alentejano**	**TOTAL (10E6 €)**	**Weight of each service in total costs (%)**
EMERG (10E6 €)	32,323	12,849	22,762	3,257	6,541	77,732	24,59
INP (10E6 €)	81,347	35,482	38,463	3,906	6,915	166,113	52,56
EC (10E6 €)	37,945	9,375	21,532	1,189	2,162	72,203	22,85
TOTAL (10E6 €)	151,615	57,706	82,757	8,352	15,618	316,048	
Weight of each hospital in total costs (%)	47,97	18,26	26,18	2,64	4,94		

Primary Care		
TOTAL (10E6 €)	**Only emergent**	**Emergent Care Weight(%)**
174,822	13,607	7,78

Global system cost (%)	Primary care weight in total costs (%)
490,87	35,61

Tested scenarios – Secondary care							
Services/ Hospitals	**Garcia de Orta**	**Barreiro**	**Setúbal**	**Montijo**	**Litoral Alentejano**	**TOTAL (Variation)**	**Weight variation of each service in total costs (%)**
EMERG (Variation %)							
Scenario I	6,65	9,22	5,82	1,07	9,94	6,87	*0,69*
Scenario II	-3,55	-3,33	-3,6	-3,35	-3,65	-3,53	*0,35*
Scenario III	-0,02	0,06	0,04	0	0,17	0,03	0,03
INP (Variation %)							
Scenario I	2,68	6,52	5,18	0,74	6,9	4,21	*0,11*
Scenario II	-2,2	-2,31	-3,18	-1,15	-2,81	-2,45	*1,32*
Scenario III	0	0,07	0,08	0	0,1	0,04	*0*
OC (Variation %)							
Scenario I	0	0	0	7,57	9,2	0,4	*-0,79*
Scenario II	-11,31	-12,2	-12,06	-13,71	-14,62	-11,79	*-1,67*
Scenario III	0	0	0	0	0,32	0,01	*-0,01*
TOTAL (Variation %)							
Scenario I	2,86	6,06	4,01	1,84	8,49	4	
Scenario II	-4,76	-4,14	-5,61	-5,61	-4,8	-4,85	
Scenario III	0	0,06	0,04	0	0,16	0,03	
Weight variation of each hospital in total costs (%)							
Scenario I	*-0,52*	*0,36*	*0,01*	*-0,05*	*0,22*		
Scenario II	*0,04*	*0,13*	*-0,2*	*0,03*	*0*		
Scenario III	*-0,01*	*0*	*0,01*	*0*	*0,01*		

Primary care		
TOTAL (variation %)	**Only emergent (variation %)**	**Emergent Care Weight (%)**
Scenario I 8,03	**Scenario I** 9,33	**Scenario I** *0,1*
Scenario II 4,65	**Scenario II** -0,1	**Scenario II** *-0,36*
Scenario III a) -20,77	**Scenario III a)** -87,63	**Scenario III a)** -6,56
Scenario III b) -15,14	**Scenario III b)** -87,63	**Scenario III b)** -6,64

Global system cost (%)	Primary care weight in total costs (%)
Scenario I 5,43	**Scenario I** *0,88*
Scenario II -1,47	**Scenario II** *2,21*
Scenario III a) -7,37	**Scenario III a)** -5,15
Scenario III b) -5,37	**Scenario III b)** -3,68

Table 3: Cost results obtained from the model. For the year 2005, these are the absolute values, and in the scenarios, the presented values represent the percentual variation between the scenario results and the ones obtained after the model's validation. The values in italic are the absolute difference between percentages.

Scenario III results show that activity in secondary care providers practically remains unchanged, but there are several changes for primary care: an easier access to services (reduction of the average time of access and queues); and a reduction of around 30% in the use of the resources. This decline seems to indicate that the reduction of the average time for ambulatory consultation using a weighed mean is unrealistic, remaining this value much more closer to the previously assumed, or that the expected gains in productivity would allow for a reduction in the total number of physicians. Either way, productivity gains are expected with this analysis, as there is a sharp decrease in the medical resources use while keeping a similar demand. Simultaneously, and from a conservative perspective (scenario III b), the costs of the primary care decrease about 15%, what would allow a global saving of 26,35 million Euros (less 5.37%) to the NHS. In the scenario III a), the global savings represent a decrease of 7.37% in the total costs.

VII. Conclusions

This study has proposed a discrete event simulation model to analyse networks of health care providers. This approach seems to be useful to analyse the impact of policy scenarios, and seems to be more appropriate than mathematical programming optimizing models. The model was implemented in Simul8 and applied to the Portuguese NHS, more particularly to the SHCR, and can be applied to other health systems or regions. Analysis has shown that the quality of results from this modeling approach depends upon the quality and detail of data routinely collected from providers.

The application of the model was calibrated and validated for the year 2005. The model was shown to produce information on a wide number of outputs that are important for planners, such as information on waiting times and queues for services, efficiency in the use of resources and the costs associated with the delivery of services.

The model was tested for three different scenarios that have indicated that: the current system is not expected to cope with an increase of 10% in the demand for services; a shift of resources from secondary to primary care and a reorganization of PCCs might improve efficiency and quality in the system (better utilization of resources and lower waiting times) as well as might decrease costs. It seems that there are potential gains from strengthening the role of PCCs in Portugal.

The results should be analysed with some caution. In addition to the difficulty in obtaining real production data concerning the health system, for the calculation of the parameters and variables required, the model described in this paper is an exploratory and generic approach to analyse networks of providers, focused on the analysis of a limited number of services and resources. Several assumptions were thus needed, that must be taken into account during the results analysis. Considering these factors, we suggest some key future developments for this work: the application of the model to other regions of the country; the modeling of other services provided by primary and secondary care providers; the inclusion in the model of tertiary care; the modeling of other resources rather than physicians; use more detailed financial information; and additional modeling of uncertainty. Underlying all these suggestions is the need to have better information systems to provide information to simulation models. Health care authorities should promote the production of this type of information, as well as to promote the development of studies to test impact of additional policies to improve efficiency, quality and costs in the system.

VIII. References

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