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# AGENT-BASED MODEL AND SIMULATION THE OUTPATIENT CONSULTATIONS AT THE "HOSPITAL DE CLÍNICAS"

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## ABSTRACT

The Hospital de Clinicas in Paraguay faces a growing demand in medical consultation. The growth affects patients waiting time in different levels. For instance, cashiers are usually saturated early in the morning. In this article, we present a agent-based model and simulations that characterize the waiting time of patients in the queues in the outpatient department of the Hospital de Clinicas. The model will help to identify weak processes in the chain in order to make rational decisions to improve the service.
The proposed agentbased model aims at optimizing the performance of the entire patients consultation process, from getting the ticket for consultation to get medical attention. The aim is to get a better understanding of the processes leading each step of the consultation and to further evaluate the different solutions that will allow to reduce patient waiting time.

## 1 INTRODUCTION

In development countries such as Paraguay, public healthcare services are always saturated. The obvious solution to this problem is to built new hospitals. However, that is not always possible given the limited resources that the government assign to to Health care. Nevertheless, weve observed that health care services are not optimize to offer the best possible service.
In fact, one of the main problems is waiting time of patients. Patients tend to go through several steps to get medical attention. In order to understand the health care process in outpatient service is important to analyze the system and simulate the impact that changes in the management of the system will have in the overall process.
This article presents a model and simulation based on agents for clinics outpatient area of the Hospital de Clinicas. Agent-based modeling is an efficient technique. (Liu, Cabrera, Taboada, Epelde, Rexachs, and Luque 2015) The agent-based model is used in biological simulations both macro level – i.e., the movement of a fish (González, Dalforno, Suppi, and Luque 2009) - and cellular behavior at micro level

(Walker, Southgate, Hill, Holcombe, Hose, Wood, Mac Neil, and Smallwood 2004). It has been also used in social sciences (Cederman 2002).
Agent based models offers some advantages such as: an increased detail in experiments based in simulation, a transparent learning process, and the ability to control and easily modify individual behaviors (Liu, Cabrera, Taboada, Epelde, Rexachs, and Luque 2015).
One of the primary applications of agent based model to hospital environments examines patient flow in Emergency Departments (ED)(Jones and Evans 2008, Friesen and McLeod 2014). The simulation provides a more secure and efficient method to test new techniques and processes in order to improve Hospital efficiency. A sufficiently complete model can be used to test real case scenarios without changes all the management system in the hospital. Additionally, a simulation can be used to test a number of possible scenarios that are too large to study in a real consultation department, and can be also done in less time.
The behavior of the system arises as a set of actions and interactions. This model describes the complex dynamics found in an outpatient department of the Hospital de Clinicas, which represents each individual and system as an individual agent. An agent can represent any type of component of the real system (Bonabeau 2002). Different types of agents, actives and passives have been identified. The active agents represent the individuals of the consultation department, in this case all the human players, such as the patients and the hospital staff (cash workers, admission staff, nurses, doctors). Passive agents represent the informatic system used in the cashier. Agents are located in a simulated environment and have the ability to interact with other agents. They make decisions based on a set of rules governing their behavior (Macal and North 2005). Moore's machines are used to represent the actions of each agent.
It should be noted that this work has been developed from a hospital emergency simulator, which have been developed as part of previous work of the research group of the Autonomous University of Barcelona (Liu, Cabrera, Rexachs, and Luque 2014).
In this article, the objective is to provide a model and simulation based on agents of the department of Outpatient Consultations of Hospital de Clinicas, in order to reduce the waiting time of patients.
In this article, the objective of the proposed agent-based model is to optimize the performance of the patient's entire process to consult, to have a better understanding of the process and to evaluate the different solutions to reduce patient waiting time.
The rest of the paper is organized as it follows. In Section II describes Agent-Based model description. Section III presents the Initial Simultation. Section IV Conclusion and Future Word. Section V Acknowledgments. Section VI references. Section VII Author Biographies.

## 2 AGENT-BASED MODEL TO OUTPATIENT CONSULTATION

### 2.1 Current process and Conceptual model of outpatient consultation departments

The conceptual model of the process for requesting a shift and making a medical consultation is shown in Figure 1.
The outpatient department includes the following areas: box, admission, nursing, central archive, waiting rooms and offices.
A patient enters the consultation department in various ways on foot, on a wheelchair or on a stretcher. Upon arrival, patients should form the queue in the cashier (or box) where the patient is given the receipt. In the box, at the beginning of the day, the officials receive the agenda of the day established by the doctors, which contains the limit of patients that will be taken care of. The box is common for all the specialties that the hospital has. Patients form a queue (waiting time for attention: $(t_{wrs})$) to be able to pay for the medical appointment, if necessary, and to withdraw the receipt. Once the box begins the attention, the officials go registering and granting the receipts to the patients (Time of the attention in the box: $(t_{rs})$), until reaching the limit of patients that must be attended in each dependency.
Once the care in the box has been completed, patients go to the office block and return to a queue (separated by dependency) to get attention in admission. When admission begins, patients submit their identity

card or passport and the duplicate of the receipt obtained in the box (Waiting time at admission: $(t_{wa})$), officials ask what type of consultation: first consultation time $(t_{af})$, control time: $(t_{ac})$, interconsulting time: $(t_{ai})$). As the consultation is the first time, the official completes the header of the patient's file with the patient's personal data, in addition to other information that the patient is asked. In case it is not the first consultation, the patient is asked to give his / her number, the number is registered in the duplicate of the receipt. The control-type consultation involves the patient who has already consulted at least once and wishes to re-consult or perform a check. Interconsultation occurs when another specialist refers the patient to that service. After an hour of admission attention, the records of the patients attended at admission are collected. The archival officer goes to the central archive to collect the necessary records, and then take them to the infirmary; until all patients have been enrolled.

The patient returns to the waiting room of the infirmary and waits for his turn (Nursing waiting time: $(t_{wn})$). Once the nurse calls the patient, she takes her physical data, her weight, height and vital signs, such as blood pressure (nursing time: $(t_{we})$). The patient is then assigned to an office. At the end of this, the patient is waiting for his / her appointment (waiting time for medical consultation: $(t_{wmc})$), in the waiting room. It may be the case that a patient comes by appointment. In that case, the patient goes to the infirmary and the nurse verifies the appointment and gives a record that the patient has an appointment. Then, the patient goes back to the box and performs the same process as the other patients except that he already has the scheduled shift.

The nurse distributes to the doctors the files of the patients that corresponds to him. The doctor proceeds to call the patient (Time of medical attention: $(t_{wm})$). If it is the first time the patient consults, he / she completes the other data of the card of the patient that has assigned to him in the admission. In addition, it completes other consultation sheets of interest, such as the treatment sheet, diagnosis, the recipe among other sheets. The doctor can assign the patient an appointment, discharge the patient or ask him to return after a certain period of time. In case you have been assigned an appointment, write down then pass all appointments to the infirmary. When all the consultations are finished, the doctor returns the files to the infirmary, where they remain until the transfer officer in charge of the file, returns them to the central file on the next day.

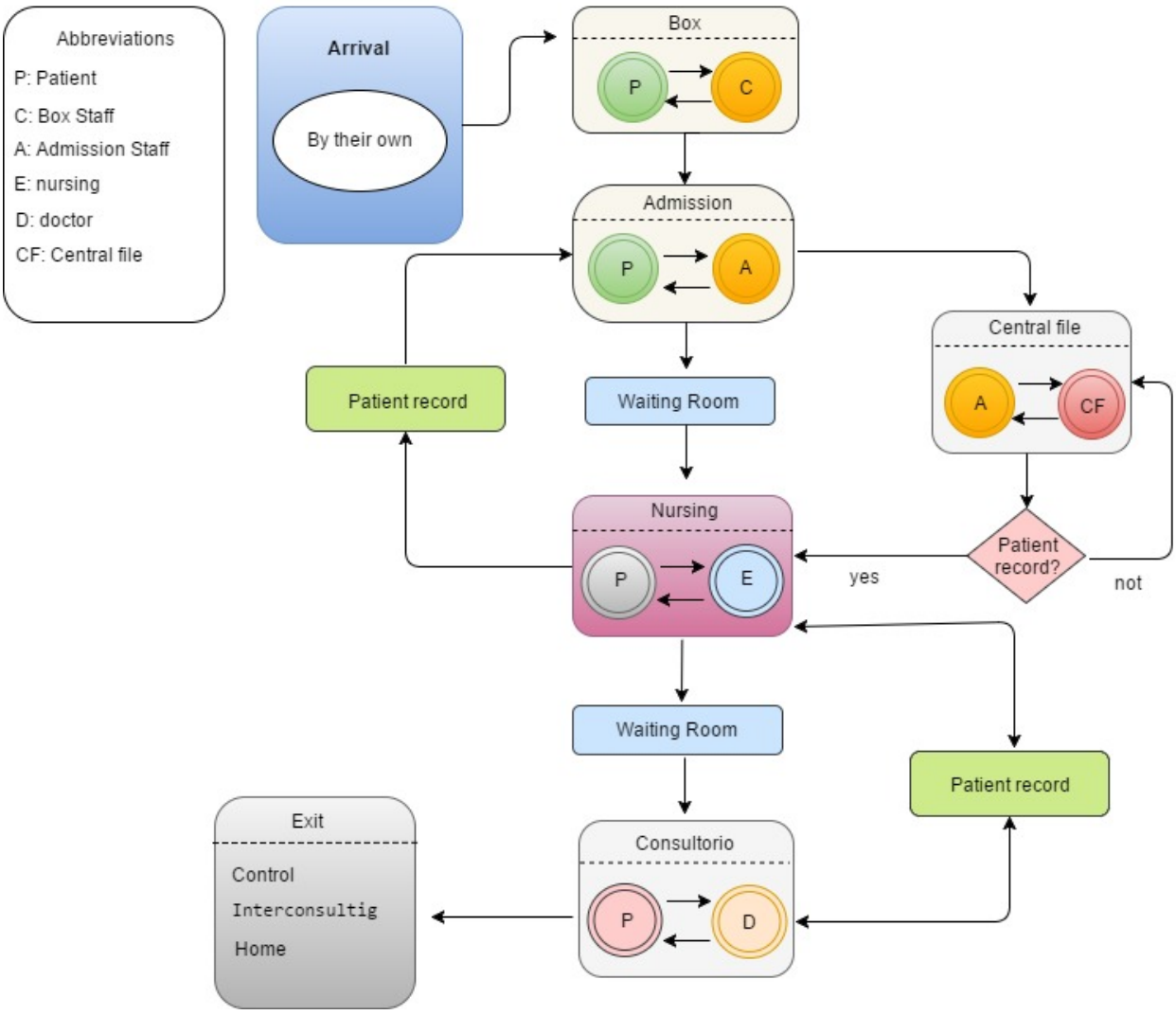


Figure 1: Conceptual model of outpatient consultation departments

### 2.2 Patient arrival

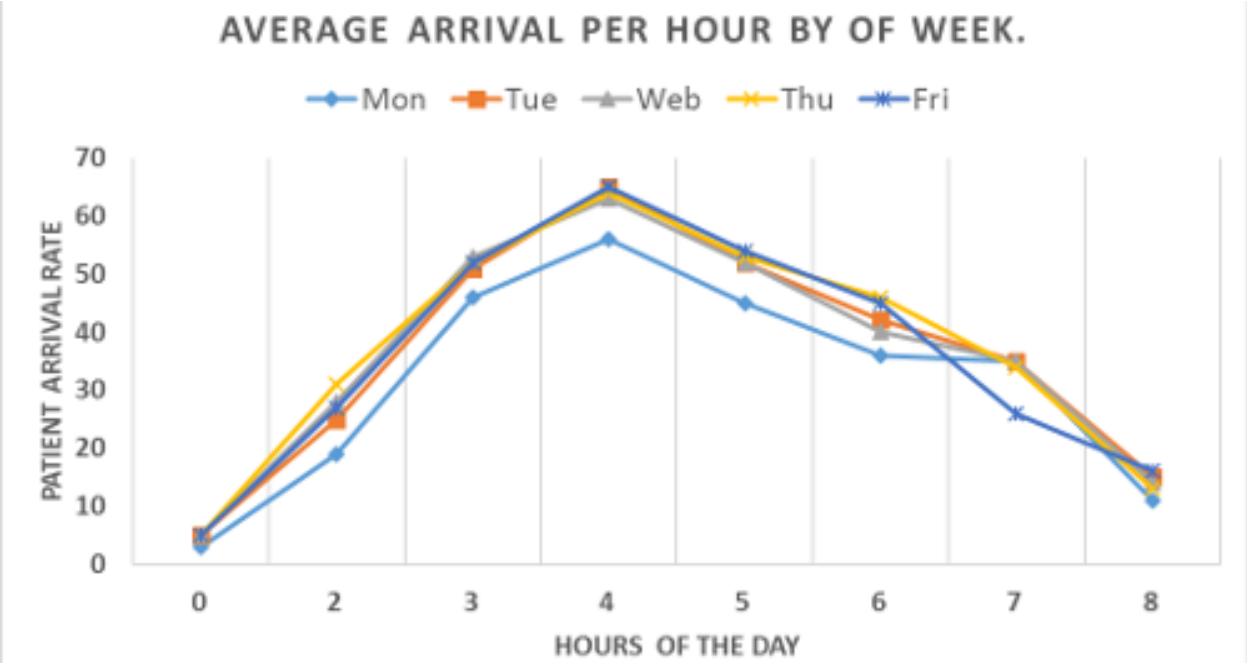


Figure 2: Average arrival per hour by day of week

The arrival intervals of the patients follow a distribution of a Poisson process with a process medium that changes depending on the day model. Although the process and means do not change between simulations, the effect of a change in the seed of randomness of a simulator execution will change the intervals and this property allows the analysis of the model statistically, using several different values for this seed.
The averages of the Poisson process have different values depending on the time of day.
We can see in figure 2 that the pattern of time of arrival of the patients in the box was stochastic with the peak of arrival between 2 and 7 am.
People who arrive from 6 to 7 am are those who have appointments or get them for the afternoon hours, due to the influx of patients arriving at the hospital, it is difficult to get an appointment for the morning hours.

#### 2.2.1 Output

The output of an agent-based simulator includes two parts, interaction information of all agents. The status information of the consultation environment, such as the number of waiting patients, use of physical resources, occupation of health personnel.
In this way, the simulator does not provide directly the information about the behavior of the simulated department, whereas the cross analysis through different simulation scenarios is the way to obtain information.

#### 2.2.2 Agent definition

Two types of agents were defined; active and passive, to represent all components of the department of outpatient consultations, human and physical resources. The active agents are all human beings that can interact with other active or passive agents. The passive ones represent all the physical resources of the ambulatory consultation department. Passive agents can only interact passively with active agents, one of the passive agents is the computer system that issues the receipt in the box. The active agents considered

in this study include: box staff, admission staff, nurses, doctors and patients.
These active agents are defined with a set of behaviors and decision rules. The behavior of agents is defined at the individual level, a set of behaviors of the health staff determines the type of service they can provide in execution, all agents follow their own rules of behavior.
The behavior of the outpatient department emerges as a result of these interactions.

## 3 INITIAL SIMULATION

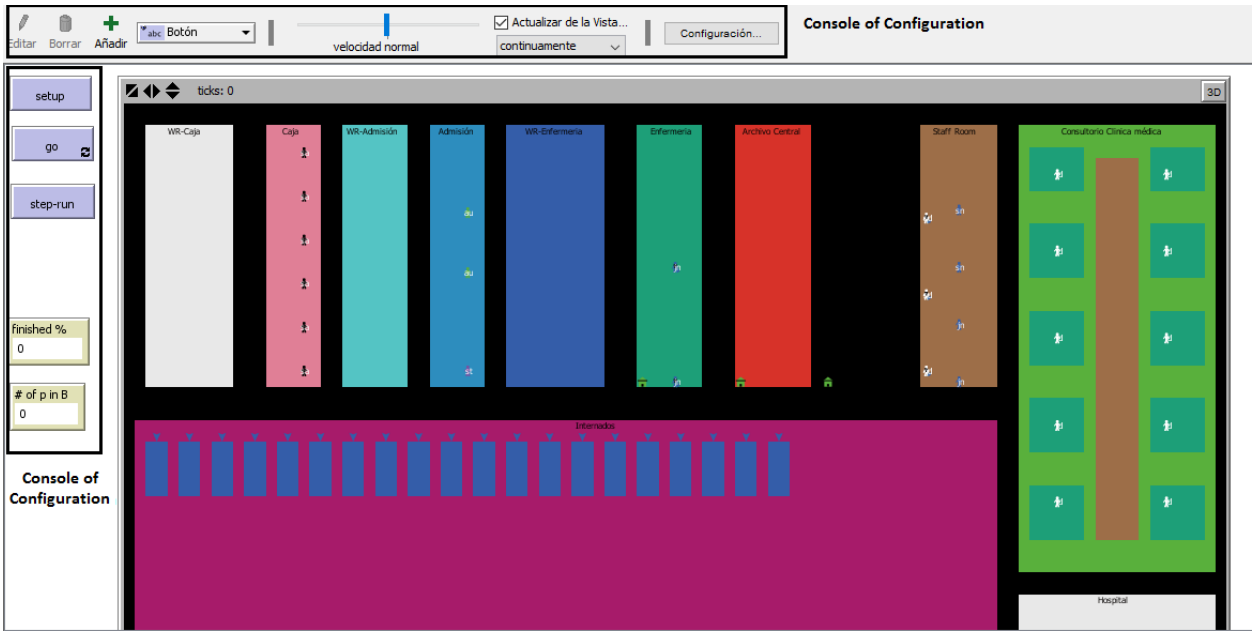


Figure 3: Simulation display in Netlogo

In order to verify the proposed model designed in the first cycle, an initial simulation has been created. Using the NetLogo agent-based simulation environment (Wilensky and Evanston 1999), a high-level platform especially suited for modeling complex systems that develop over time (Allan 2009).
NetLogo allows visualizations of actions and agent interactions, a very important aspect considering that a primary use of the tool is to gather feedback from the staff working in the outpatient department of the Hospital de Clinicas.
The scenario adopted for this initial stage is to simulate the patients who move through the department of consultations that include the following areas: box, admission, nursing, central file, waiting rooms, offices. The types of active agents represented in this simulation are patients, admission staff, box staff, nurses and doctors.
In the case of active agents, two different levels of experience have been considered (low, labeled as junior and high, labeled as senior). The less experienced user will need more time to carry out their part of the process than the most experienced. The time of the agents is fixed internally by the programmer, but the user of the simulator can easily define the number of each type of personnel and their level of experience using the “configuration console”.
In order to make a preliminary demonstration of how a simulation can be reproduced using only a few parameters, a simplified set of patient attributes has been defined and a patient flow less complicated, the current process is followed.

Therefore, patients are shown following the same path, although in reality they are treated differently depending on the level of severity of their condition. The time of the doctor's attention varies according to each patient and its level of severity or if it is the first time that comes to consult. The arrival of the patient to the consultation department can be easily defined by the user through the configuration console of the simulator. Figure 3 shows a static view of the user interface.

### 3.1 Experiments and Discussion

As for the capacity of an ambulatory consultation simulator, we are considering two aspects. On one hand, a well-designed simulation model allows the managers of the consultation department to answer important questions about what to do if they make physical changes in the department and do not endanger patients. On the other hand, the simulation model can provide more detailed information about the behavior of the department, a better understanding of the bottlenecks.

#### 3.1.1 Outpatient consultation departments resources configuration

The department of ambulatory consultations, is defined by the configuration of human resources. Table 1 shows the value of the parameters to represent the simulated outpatient department.

Table 1: Quantitative representation of the simulated outpatient consultation departments.

| Label | Interpretation | Number |
|---|---|---|
| jC | junior box staft | 2 |
| sC | senior box staft | 2 |
| jA | junior admission staft | 2 |
| sA | senior admission staft | 2 |
| jCF | junior central file | 1 |
| sCF | senior central file | 1 |
| jN | junior nurse | 2 |
| sN | senior nurse | 2 |
| jN | junior doctor | 9 |
| sN | senior doctor | 1 |

Netlogo stores information about everything that happens during the execution of the simulator and allows the modeler to create reports that can be exported and treated with statistical and data mining tools. In this first part, we have analyzed the time each patient has spent in each of the areas of the department of outpatient consultations such as the box, admission, nursing, clinic and see the different scenarios to reduce the waiting time of patients. A collection of data has been previously performed at the Hospital de Clinicas for approximately two months to obtain real values.

To analyze the behavior of the simulator against the variables that have influence in the department of consultations, several simulations with different values have been performed to observe what results could be obtained.

We performed an initial simulation in the box, because it is one of the critical points where there is a lot of patients. Reducing the average waiting time and the number of patients who remain in the waiting room of the box, should improve the attention and waiting time.

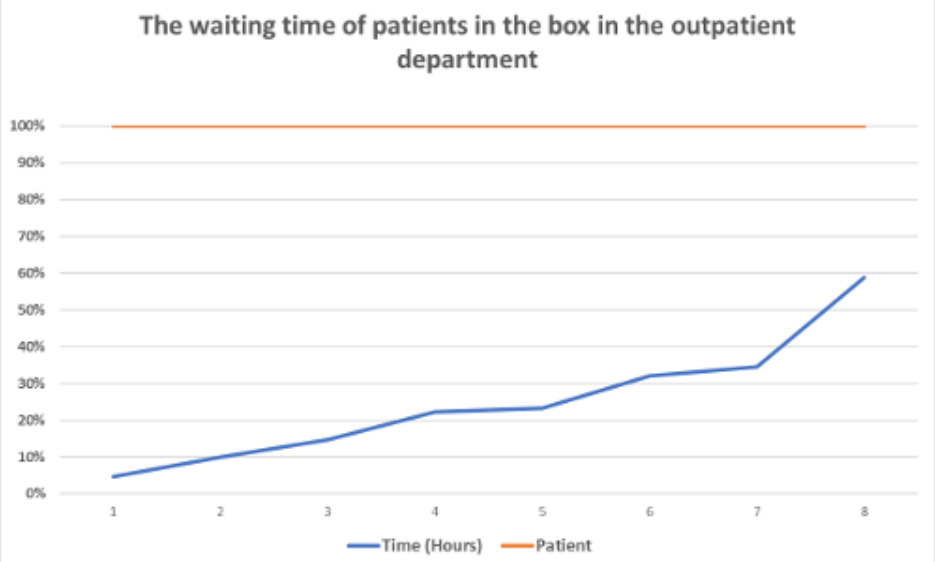


Figure 4: The waiting time of patients in the box in the outpatient department

Figure 4 shows the waiting time of the patient in the area of the box to obtain his turn, the simulation was performed with 2 staff at the box, you can observe the average hours that the patient has to wait in line when they arrive at the hospital. The least amount of human resources at the box, the longer the waiting time till the patient sees the doctor.
In this case, we assume that the hospital manager proposes a solution to add two more technicians to the box once opened. When testing and evaluating the proposed solution, we simulate this new configuration of resources by modifying the configuration of the human resources of the box used in Figure 4, the result is shown in Figure 5.

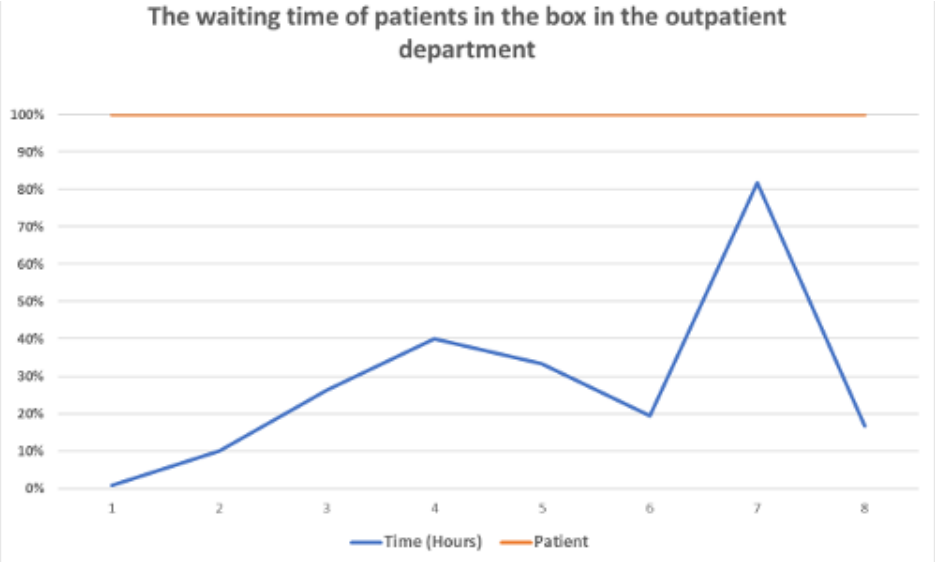


Figure 5: The waiting time of patients in the box in the outpatient department

In figure 5, the result of the simulation is observed adding two more human resources in the box. The more amounts of human resources at the box, the less is the waiting time till the patient.

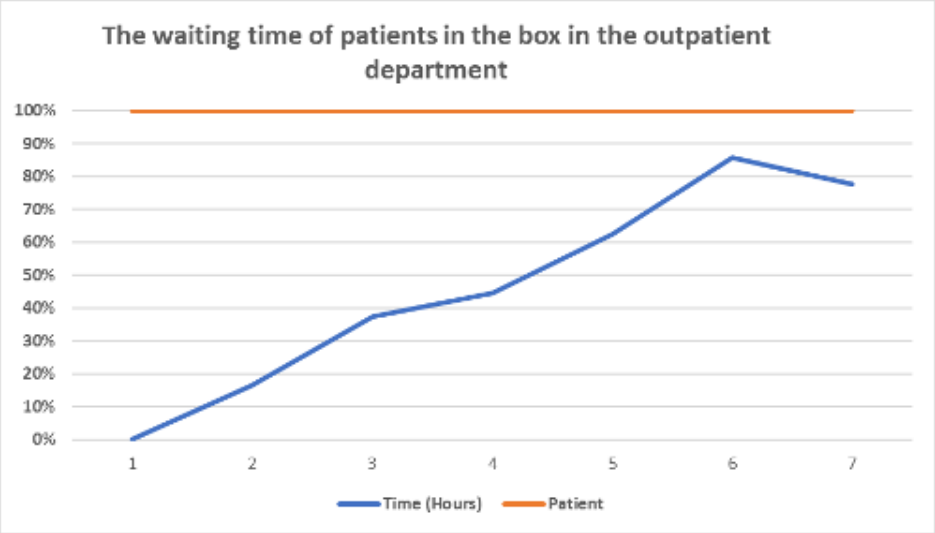


Figure 6: The waiting time of patients in the box in the outpatient department

In Figure 6, we can observe the result of the simulation adding 2 more human resources in the box. Having a total of 6 personal at the box. The greater the amount of human resources in service, the shorter the waiting time for the patient.

## CONCLUSIONS AND FUTURE WORD

This article presents an approach to better understand the department of ambulatory consultations through the simulation of the individual behavior of its components with the Netlogo tool. The agent-based modeling technique was used to simulate the behavior of the system components. The behavioral simulation model can generate interaction information under consolidation scenarios.
This work will help reduce patient waiting time and gain additional insight into the organization of patients and doctors. It will also help optimize resources.
Our future work is to add more details to the simulator and include the admission section, signins to make it as real as possible.

## ACKNOWLEDGMENTS

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