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Modelling product delivery process policies in pharmaceutical services to decrease service saturation due to Covid-19 in Colombia

Modelado de políticas de procesos de entrega de productos en servicios farmacéuticos para disminuir la saturación de servicios por el Covid-19 en Colombia

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ABSTRACT

Public health in Colombia suffered a severe blow in 2020 due to the global crisis generated by the Covid-19 pandemic that impacted a broad spectrum of human activities. Because pharmaceutical services are part of the health sector, they experienced a progressive increase due to the need for prevention and mitigation products. Thus, this sector requires transformations in the policies and procedures according to the public policies established by national and international entities of the health sector. The purposes of this work were to evaluate improved policies in accordance with the standards established by health regulatory entities and evaluate alternatives for the provision of the service based on technological simulation tools using the Vensim software tool. The simulations made it possible to evaluate the behavior of improved policies related to electronic billing and home service, and their performances were compared to several variables, such as the agglomeration of people, workload, and number of COVID-19 infections. The results showed greater effectiveness during the simulated hours, which helped to reduce the capacity of people in a given location and therefore, the risk of contagion that this could cause.

Keywords: System dynamics, Covid-19, sustainability, pharmaceutical services, computer modelling.

RESUMEN

La salud pública en Colombia sufrió un duro golpe en 2020 debido a la crisis mundial generada por la pandemia del Covid-19 que impactó un amplio espectro de actividades humanas. Debido a que los servicios farmacéuticos son parte del sector salud, experimentaron un aumento progresivo debido a la necesidad de productos de prevención y mitigación. Así, este sector requiere transformaciones en las políticas y procedimientos de acuerdo con las políticas públicas establecidas por las entidades nacionales e internacionales del sector salud. Los propósitos de este trabajo fueron evaluar políticas mejoradas de acuerdo a los estándares establecidos por los entes reguladores de salud y evaluar alternativas para la prestación del servicio con base en herramientas tecnológicas de simulación utilizando la herramienta de software Vensim. Las simulaciones permitieron evaluar el comportamiento de las pólizas mejoradas relacionadas con la facturación electrónica y el servicio a domicilio, y se comparó su desempeño con diversas variables, como la aglomeración de personas, la carga de trabajo y el número de contagios de COVID-19. Los resultados mostraron una mayor efectividad durante las horas simuladas, lo que ayudó a reducir el aforo de personas en un lugar determinado y, por lo tanto, el riesgo de contagio que esto pudiera ocasionar.

Palabras clave: Dinámica de sistemas, Covid-19, sustentabilidad, servicios farmacéuticos, modelado computacional.

1. INTRODUCTION

Different studies suggest that technology could be a useful tool to mitigate the effects of the global Covid-19 pandemic [1]–[4]. Technologies, such as contact tracing [5], drones [6] and robots, are tools that could help society define public health policies and social policies [7]. However, the pandemic is continuing, and it is too early to be able to assess the effect and efficiency of the innovative technological contributions developed in response to the crisis [4]. The reported experience is not clear, and thus, the overall effectiveness of the approaches is still uncertain [8]. However, mathematical modeling has enabled a rapid interpretation of the dynamics of the Covid-19 pandemic [9].

Sectors, such as the consumer market, had to make changes in the way they provide their products to the consumer and comply with measures determined by each government to prevent the massive spread of the virus [10], [11]. Certain economic activities had to cease due to the social isolation mandates, but other activities saw a significant increase in their direct sales and the flow of people, such as medicines sales, sales of basic food staples, sales of cleaning products, among others. Similarly, the role of technology also increased [12], [13]. Health sector personnel are one of the most susceptible to being infected, since daily and continuous exposure to possible transmitters of Covid-19 makes this a latent risk in their daily work [14], [15].

It must be taken into account that in addition to the high risk of contagion to health sector personnel, there were other types of inconveniences they had to face [16]. These inconveniences included an increase in the flow of patients that were and were not infected with Covid-19 and the lack of preparation for the pandemic. Since there were no clear protocols and policies to deal with the Covid-19 pandemic, there were no immediate adaptive measures, which resulted in a lack of personal protection equipment, supplies and medicines, for example [17].

In general, the definition of pharmaceutical services includes mainly pharmacy chains, such as outpatient pharmacies located in primary care clinics, that focus on dispensing prescription medicines and providing basic pharmacy services. In addition, these pharmacy chains can also sell over-the-counter medicines, supplements, and other healthcare-related products and devices [18].

In Colombia, the regulatory entity for pharmaceutical services is the National Institute for Food and Medicine Surveillance – Invima [19]. Based on the definition from Invima, the pharmaceutical service is the health care service responsible for activities, procedures, and interventions of a technical, scientific, and administrative nature, related to medicines and medical devices used in health promotion. The prevention, diagnosis, treatment, and rehabilitation of the disease, contribute harmoniously and integrally to the improvement of the individual and collective quality of life [19]. Thus, pharmaceutical services must strive to prevent disease and improve the quality of life and health of people while not negatively affecting their well-being. Also, pharmaceutical companies experience a constant and growing demand, especially when public health is negatively impacted, which leads to an increase in the flow of individuals in these businesses [19].

According to the global health problem that has been occurring due to the spread and accelerated growth of contagions due to the Covid-19 virus, health services, and especially the pharmaceutical sector, have shown growth in the volume of users. Low-complexity pharmaceutical services, in particular, are one part of the system that has become saturated. A recent study of consumption trends in Colombia shows a 45% increase in the consumption of pharmacy products [20].

The problem of agglomeration acquires greater relevance and causes concern, since this is a visible source of the spread and contagion of the virus due to the high flow of people in closed and open spaces. This problem has shown the need to create alternatives and define new methodologies to mitigate and prevent the spread of the virus in users and workers who constantly go to pharmacies.

Due to Covid-19, MinSalud has innovated solutions in an accelerated manner. We had to make changes in pharmaceutical policy by implementing new technological developments to respond to the pandemic [21]. Therefore, it is necessary to create and implement plans or improvements that help reduce the flow of people in these pharmacy and thus, mitigate the spread of the virus.

The health crisis forced all organizations to adapt to continue providing their services [15], [22]. This was the case for supply points (stores, supermarkets, and department stores); in addition, pharmaceutical services had to find a way to improve their processes [18], [23], [24]. The pharmaceutical services sector, in particular, had to overcome difficulties to be able to continue to provide services, such as:

- Quality systems that were not designed to avoid excessive saturation
- Lack of staff
- Lack of technologies that allow greater agility in the service

The purpose of this work is to improve the ability to provided pharmaceutical services by strengthening and adapting the Quality Management Systems (QMS) and applying technologies and technological instruments that allow greater agility. As a consequence of these measures, the number of people in the pharmacy would decrease, which would benefit the users, patients, customers, and society overall by mitigating and reducing the risk of contagion of the Covid-19 virus. Thus, this study makes a proposal that mitigates or reduces the flow of people in pharmacy without affecting the service they provide, and thus, reduces the risk of contagion and spread of the virus in these pharmacy.

This work is of an exploratory type defined as "*That which is carried out on an unknown or little studied subject or object, so its results constitute an approximate vision of said object*" (Morales, 2012). According to the above, the search herein was based on a systematic review of the literature [25] in several databases, such as Scopus, Lilacs, and Google Scholar, for topics related to system dynamics, pharmaceutical services, and Covid-19. The problem to be investigated was related to "the saturation of low-complexity pharmaceutical service due to Covid-19". Subsequently, the articles that had some relationship or partially clarified the topic of interest were classified, organizing the analysis of each work.

The search was initially carried out in the Scopus digital library, referencing the search string: "system dynamics" Covid-19, which identified 26 articles; and "pharmacy AND Covid-19" and "pharmaceutical strategies" Covid-19, which identified 1 and 3 articles, respectively. In the LILACS library, the keywords "system dynamics Covid-19" and "Covid-19 and labor market" were entered, which identified 31 and 62 articles, respectively.

2. METHODOLOGY

To model the problem of agglomeration or high flow of users in these pharmacy, tools based on system dynamics were used, which is a methodology designed to solve specific problems. According to [26], system dynamics was initially conceived to study the problems that arise in certain companies where delays in the transmission of information, together with the existence of feedback structures, give rise to undesirable modes of behavior, such as oscillatory behaviors.

The tool that helped us to represent or build the model is the causal diagram, which is a useful instrument in system dynamics. This type of diagram shows the feedback structure of a system. In addition, causal diagrams observe and illustrate mental maps and develop and evaluate models to provide a better understanding of a system. The causal diagram is also often called a dynamic hypothesis [26]. After a causal diagram is developed, a Forrester diagram (Flow and Level Diagram) is usually used. This shows the relationships between the variables of a system; these variables are usually classified as level, flow, and auxiliary. The Forrester diagram is a reworking of the influence diagram. It also receives the denominations of diagrams of flows and levels, of flows-levels, or dynamo diagrams.

The application of system dynamics and the construction of the aforementioned diagrams allowed us to model and evaluate alternatives to improve the stated problem and assess possible solutions to it.

2.1. Dynamic Hypothesis

The causal diagram was constructed and modeled the problem to be addressed. First, the variables that directly and indirectly intervene in the saturation of the pharmaceutical service were determined. Second, the definition of these variables were determined so they could be described. Finally, the respective polarization was carried out and the cycles within the system were defined (see Figure 1).

2.1.1 System cycles

Next, the different cycles that were considered to be the most important within the system were determined and are presented in Table 1. The relating variables and a brief description of the resulting behavior are shown in Figure 2.

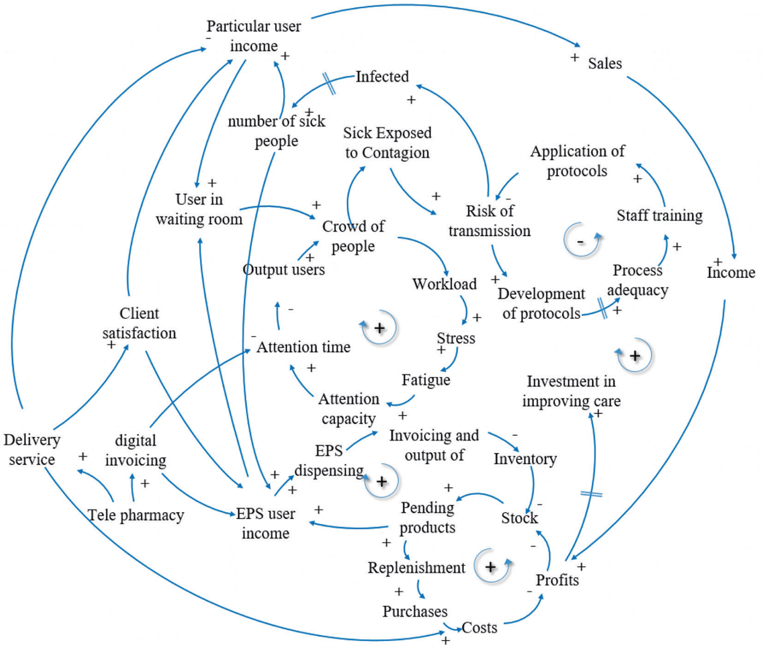
Table 1. The six system cycles.
Tabla 1. Los seis ciclos del sistema.

Id	Cycle name
1	EPS (Entidades Promotoras de Salud) user entry cycle
2	Cycle agglomeration of people on the risk of contagion COVID-19
3	Cycle entry private customers
4	Product stock cycle on replenishment
5	Workload cycle
6	Development cycle of biosafety protocol on COVID-19 risk

EPS user entry cycle: This cycle shows how user input EPS and dispensing product greatly affects the inventory. This is because patients completing medical consultation and users requesting drugs increase the number of users. During the dispensing, the billing and exit of the system of these products are carried out, negatively affecting the inventory; as a consequence, the stock decreases. By reducing the stock, the availability of some products could decrease, increasing the number of medicines pending delivery. The stock could be lowered and increase the number of pending orders. In the end, the greater the number of individuals with pending orders, the greater the user income.

Cycle agglomeration of people on the risk of contagion Covid-*19*: This cycle models the behavior of high flows of people in the same place, which is related to the risk of contagion by Covid-19. The greater the agglomeration of people is, the greater the number of users exposed to a probable contagion. Therefore, if the number of infected people increases, the number of sick people increases, which increases the number of patients, repeats the cycle, and reinforces it.

Figure 1. Causal diagram modeling product delivery process in pharmaceutical services (source: Authors).
Figura 1. Diagrama causal que modela el proceso de entrega de productos en los servicios farmacéuticos (fuente: Autores).



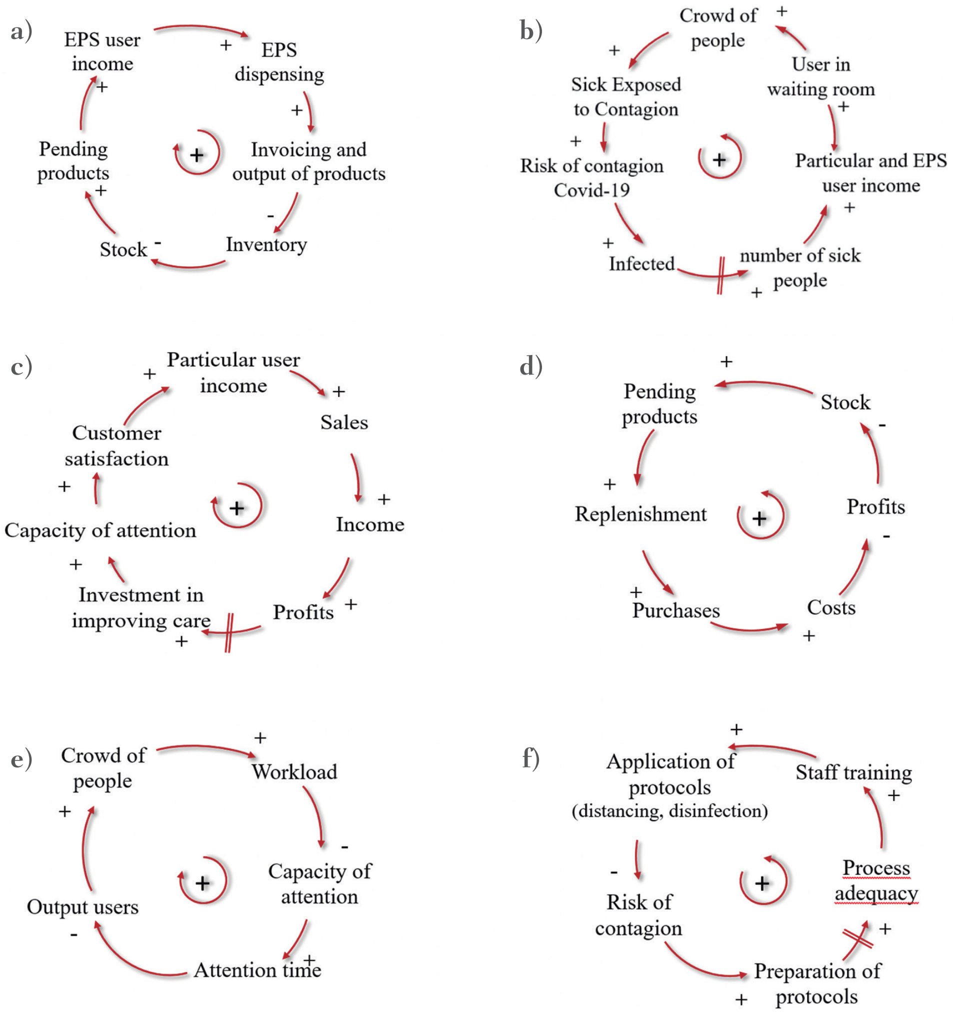
Cycle entry private customer: This cycle describes the impact that the income of private users has on the profits due to an increase in sales. With an earnings growth, investments can be made in hiring, locations, equipment, software, and process improvements, for example. An increase in investments increases the attention capacity of the employees and income of the business, which in the end reinforces the cycle.

Product stock cycle on replenishment: This cycle models the relationship between the increase in pending medications and perceived earnings. The increase in pending drugs generates an increase in the replacement of products since a new order must be generated to meet this need. As replenishments increase, purchases increase, increasing the expense generated, which in the end decreases the profit.

Workload cycle: This cycle models the relationship of the increase in the workload on the attention of the employees, which increases the flow of people. An increase in the workload reduces the attention span due to overexertion and fatigue in employees. The foregoing generates an increase in the attention time, generating a greater agglomeration of people at the site and therefore a greater workload, thus, reinforcing the cycle.

The development cycle of biosafety protocol on Covid-19 risk: This cycle shows the relationship of the risk of contagion by Covid-19 when measures, such as biosafety protocols, are developed and applied. By applying the measures framed within the protocol, the space and therefore, the people within the establishment, decrease, which leads to a decrease in the risk of contagion. Due to this, the implementation of the protocol is reinforced to not allow the risk to be raised, which balances the cycle.

Figure 2. System cycles (source: Authors).
Figura 2. Ciclos del sistema (fuente: Autores).



2.1.2 Flow and Level Diagrams

In the flow and level diagram, six key variables can be observed, which are the level variables of the problem (See Figure 3). The first variable is Inventory, and this changes depending on the replenishment of the products, increasing to the desired level of inventory. It decreases according to the amount of the sales with a home delivery. The Investment Budget is a variable that increases depending on the number of EPS and Non-EPS (private/particular) customers and decreases depending on the amount of investment made in improving care and home costs and the purchase of products to maintain inventory. The number of people sick from Covid-19 is based on historical data retrieved from the public information provided by authorities. The amount of trained personnel working in the direct customer service area increases depending on the number of servers and the training time, reaching the maximum when the total number of servers has been trained. For the variable Users in the waiting room, it is observed that there is an entry of EPS customers and private customers, therefore an agglomeration is generated that can produce an increase in the number of people infected by Covid-19. Subsequently, after being attended to, they go to billing and leave the system. It must be taken into account that these users generate work stress to the servers that the system has; therefore, the perception of workload is modified depending on this agglomeration. The rest of variables of the model are described in Table 2.

3. RESULTS

Some of the data entered for the validation of the model came from an interview with the director responsible for one of the low-complexity pharmaceutical services where delivery is made for both EPS and the private sale of pharmaceutical products. The other data were assumptions used in the development of the model, which should show results close to those observed in the real system.

It is possible to measure the degree of effectiveness of the electronic billing and home service application and make a comparison on how the behavior of the agglomeration of people impacts contagion by Covid-19.

A simulation was carried out on the entrance behavior of users. This was used to demonstrate the hypotheses about how the agglomeration of people in the establishment increases and its impact on the contagion and number of patients with Covid-19. This was carried out for five days or 60 working hours, taking into account that the hours of operation are 12 hours a day. Graphic results according to the information entered were observed.

For the explanation and analysis, the following scenarios were considered that focused on variables whose impact was more relevant on the results obtained according to the objectives set. In addition, graphics produced in the Vensim program were used. Also, the results showed how the program simulated the current problem of agglomeration of people and its repercussions on the health of users and employees; for example, variables such as workload, COVID-19 contagion, and number of sick people were observed. The behavior of some variables that arose due to the implementation of policies, such as electronic invoicing and home delivery, was determined.

3.1.1 Trend scenario 1 hypothesis: Agglomeration of people, number infected with Covid-19 and workload without improvement policy

This hypothesis began with the variable of agglomeration of people, where the number of customers in the place was the sum of users in the waiting room and people in billing. Starting from the data provided by the interviewee, there were 20 users who entered by EPS and 10 by a private income. It was assumed that for the system it would be 30 users and 6 servers, that is, 36 people, which was the maximum capacity. Taking into account that the variable people in billing was a constant during the simulated period of 6 people, it was observed that the agglomeration depended on the number of users in the waiting room.

As shown in Figure 4a, the relation of the people in billing and users in the room shows that the number of users in billing remained constant, while users in the room tended to grow throughout the simulated period. The agglomeration of people increased; that is, the more the hours were the greater the accumulation of users in the place.

As a consequence of the previous variable, the number of people infected with Covid-19 increased. This variable is of great importance for the achievement of the objectives, since the problem solution lies in reducing the number of infections that may occur in the establishment due to the high flow of people in the place. The impact of the agglomeration of people on it was direct; that is, if the previous variable increased, it increased, and in the opposite case, it decreased.

As shown below in Figure 4b for people infected with Covid-19, there was a slight decline during the first three hours of the simulated 60 hours. After this, there was an increase in the number of infections, with an increasing trend during the rest of the simulation.

Another variable that is a consequence of the agglomeration of users is of the number of sick people. As this depends on the contagions, it can be observed that its growth was exponential. This growth was due, in large part, to the recovery period, which is 10 to 14 days. Therefore, more than 180 hours must be simulated to observe the effect of the number of recovered people. As seen in Figure 5a for sick people, there was always growth during the simulated period, which was greater than 20 hours. This simulated trend is consistent with reality, considering the premise that the symptoms or illnesses appear three or four days after infection.

The workload variable, also associated with the agglomeration of people, increased, as shown in Figure 5b. From 10 to 12 simulated hours is above 1%, the workload increased, which indicates that the work performed by the servers was above their normal capacity, and this was due to the increased flow of people in the place.

Figure 3. Flow and level diagram (source: Authors).
Figura 3. Diagrama de flujo y nivel (fuente: Autores).

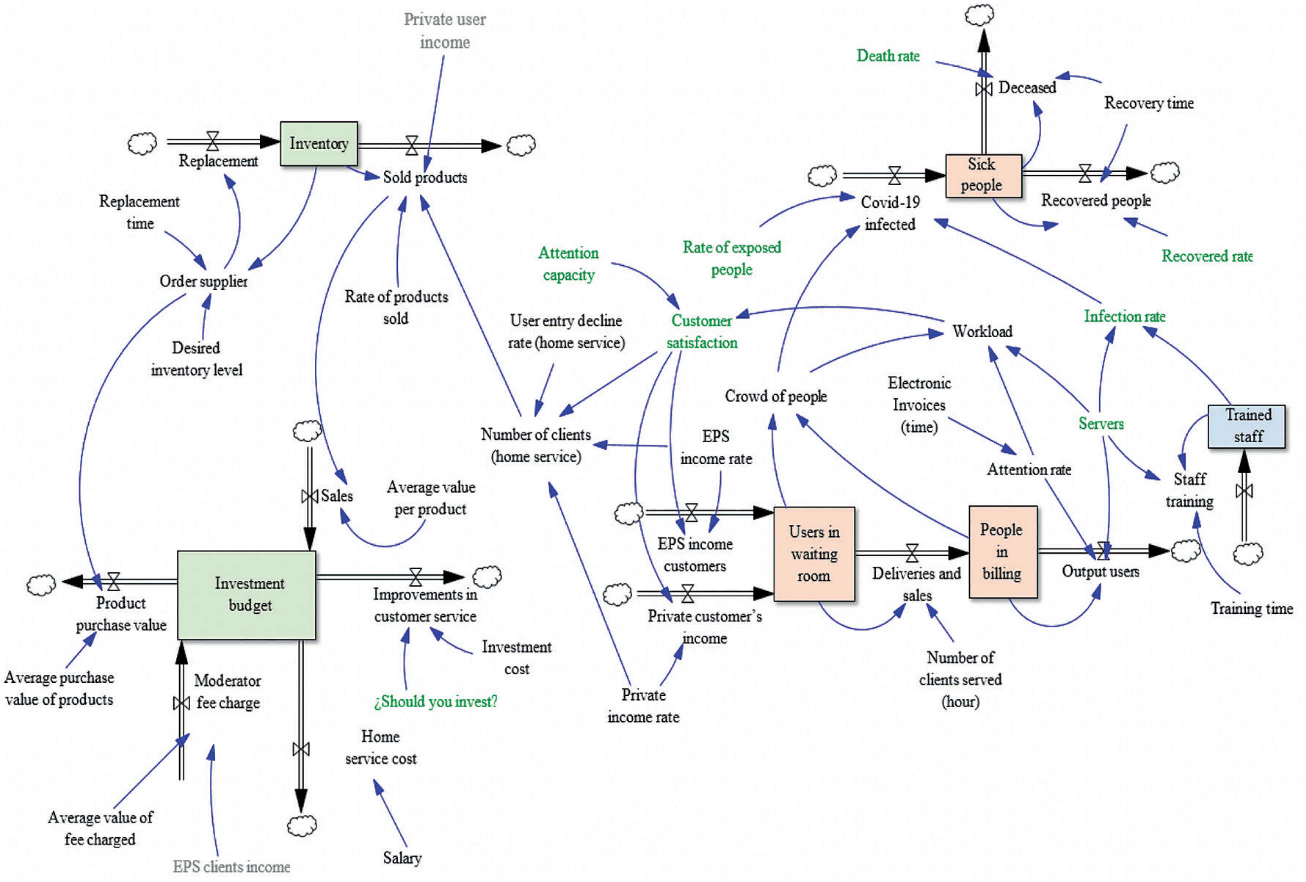
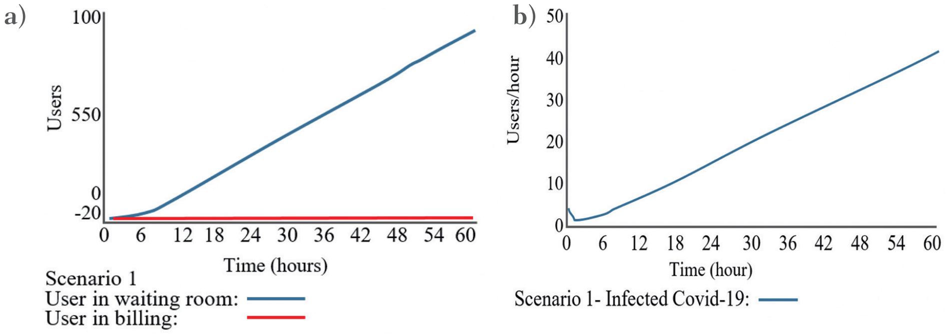


Table 2. Variables and their descriptions (source: Authors).
Tabla 2. Variables y sus descripciones (fuente: Autores).

Name	Type	Description	Units
Users in waiting room	Level	EPS income customers + Income private customers - Dispensation and sales	Person
People in billing	Level	Dispensation and sales - Output users	Person
Trained personnel	Level	Personnel in training	Person
Sick people	Level	Infected COVID-19 - Deceased - Recovered people	Person
Inventory	Level	Replacement - Sold products	Product
Investment budget	Level	Moderator fee charge + Sales - Home service cost - Improvements in care - Product purchase value	Pesos
EPS income customers	Flow	EPS income rate * (Customer satisfaction + 1) / 2	Person/hours
Income private customers	Flow	Private income rate * (Customer satisfaction + 1) / 2	Person/hours
Output users	Flow	IF THEN ELSE((People in billing) - (Servers * Attention rate)> 0, (Servers * Attention rate), People in billing)	Person/hours
Dispensation and sales	Flow	IF THEN ELSE (Users in waiting room-Customers attended x hour> 0, Customers attended x hour, Users in waiting room)	Person/hours
Infected COVID-19	Flow	Agglomeration of people * (Contagion rate + 1) / 2 * Exposed rate	Person/hours
Recovered people	Flow	DELAY FIXED (Sick people * Recovery rate, Recovery time, 0)	Person/hours
Deceased	Flow	DELAY FIXED (Sick people * Death rate, Recovery time, 0)	Person/hours
Personnel in training	Flow	(Servers-Trained staff) / Training time	Person/hours
Sold products	Flow	IF THEN ELSE (Inventory - ((Customers x domicile +Income private customers) * Rate of products sold)> 0, (Customers x domicile + Income private customers) * Rate of products sold, Inventory)	Person/hours
Replacement	Flow	Order from supplier	Person/hours
Sales	Flow	Sold products * Average value per product	Pesos/hours
Product purchase value	Flow	Order from supplier * Average value purchases products	Pesos/hours
Improvements in care	Flow	Investment cost * “inverts?”	Pesos/hours
Moderator fee charge	Flow	EPS income customers * Average fee collection value	Pesos/hours
Home service cost	Flow	House salary	Pesos/hours
Crowd of people	Variable	Users in waiting room+ People in billing	Person/hours
Workload	Variable	Crowd of people /(Servers * Attention rate)	Dmnl
Customer satisfaction	Variable	Attention capacity (workload)	Dmnl
Customers by address	Variable	Decrease rate of user entry x addresses * ((Customer satisfaction + 1) / 2) Private income rate	Person/hours
Order from supplier	Variable	(Desired Inventory Level-Inventory) / Replenishment Time	Products/hours

Contagions are associated with an exposed rate of 0.08%, and this value is hypothetically determined.

Figure 4. a) Relationship between number of people in billing and users in the room, b) Behavior of infected people.
Figura 4. a) Relación entre número de personas en facturación y usuarios en la sala, b) Comportamiento de las personas infectadas.

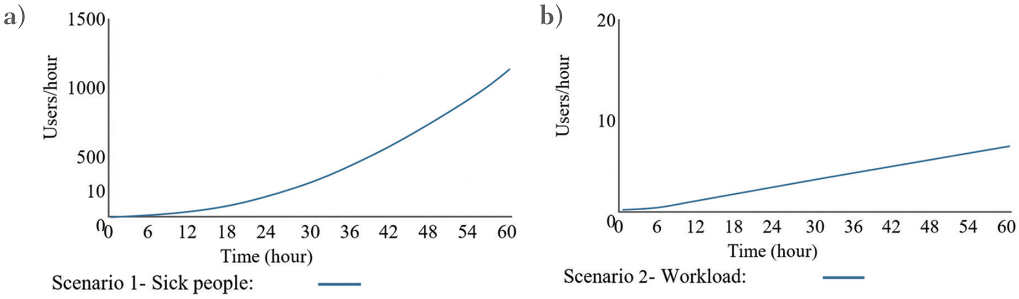


3.1.2 Trend scenario 2 hypothesis: Agglomeration of people, number of Covid-19 infections and workload with improvement policy

For this scenario, the application of improved policies was taken into account, where the main objective was to reduce the admission of patients, creating alternatives for the delivery of products, and speeding up the process by applying these.

The variable of electronic invoices is one of the policies that was implemented and had a significant impact on the workload and flow of people. By applying it, a load reduction and agglomeration behavior was observed. For this policy, a value of 100 invoices per hour was entered, and this value was hypothetical. It took into account that with its application, the attention time per user was reduced, and starting from the same 6 servers, on average it would be 15 invoices for each server.

Figure 5. a) Behavior of sick people (Scenario 1), b) Behavior of sick people (Scenario 2).
Figura 5. a) Comportamiento de los enfermos (Escenario 1), b) Comportamiento de los enfermos (Escenario 2).



According to the results obtained through this policy, there was a considerable reduction in the workload, achieving an effect below 1%, as shown in Figure 6a. The trend for workloads Scenario1 vs Scenario2 indicated that people were working at normal capacity and servers were not overloaded.

Another variable that was affected by this policy is the agglomeration of people. During the same simulated period, it was observed that the values were lower than those observed in scenario 1 (See Figure 6b). The above positively affected the number of infected and sick people, resulting in a decrease in both. In Figure 6c, the parallel made in the behavior of this variable with and without the application of policy can be observed. It shows a significant improvement in the number of infected during the simulated period.

The second policy applied is the Customers by Domicile variable, which attempted to reduce the entry of people to the place. This variable is associated with a decrease rate of entry by domiciles and acted as a controller. As shown in Figure 7a, there was a decrease rate of one, whose value was hypothetically determined. A growth of these customers occurred after five or six simulated hours. This is positive since they were customers who previously entered in person and who did not enter to saturate the system.

Other variables to take into account are inventory and investment budget. The inventory outputs the products sold, as shown in Figure 7b. Inventory had a decay from the eighth simulated hour. Regarding the customers by domicile, since more customers increased the number of products sold, the inventory decreased.

As shown in Figure 7c, the investment budget increased after the eighth simulated hour, which is positive, since it depends on making improvements in the processes of the organization. This increase was due to an increase in certain variables, such as sales. This trend is related with the above trend, since the higher the number of products sold is, the higher the sales and the higher the budget.

Figure 6. Comparison between sceneries a) The trend for workloads,
b) the agglomeration of people, and c) the number of infected and sick people.
Figura 6. Comparación entre escenarios a) La tendencia de las cargas de trabajo,
b) la aglomeración de personas, yc) el número de personas contagiadas y enfermas.

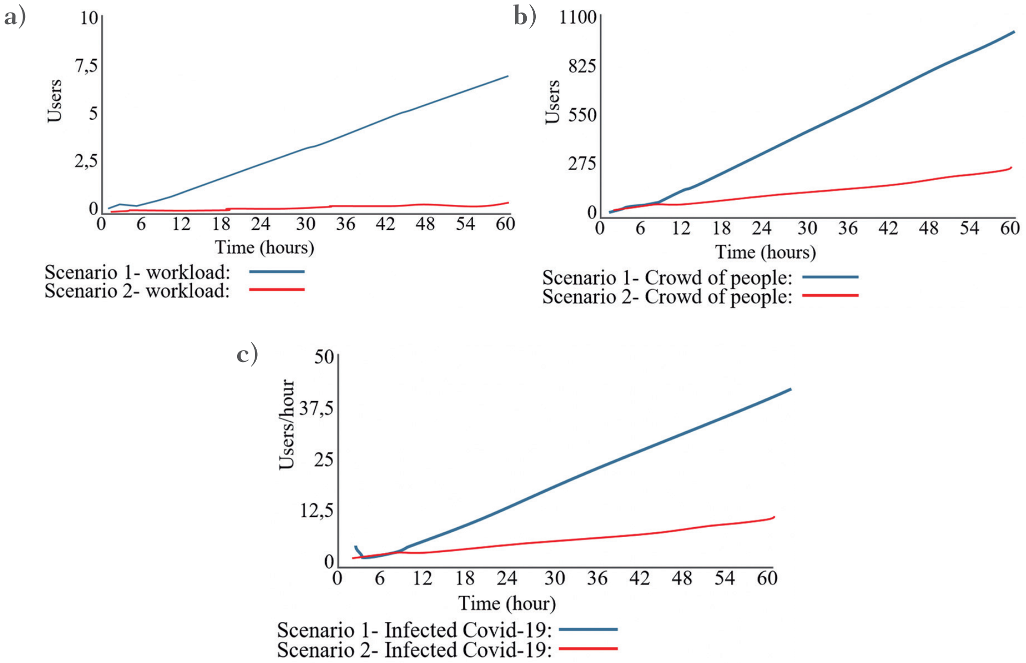
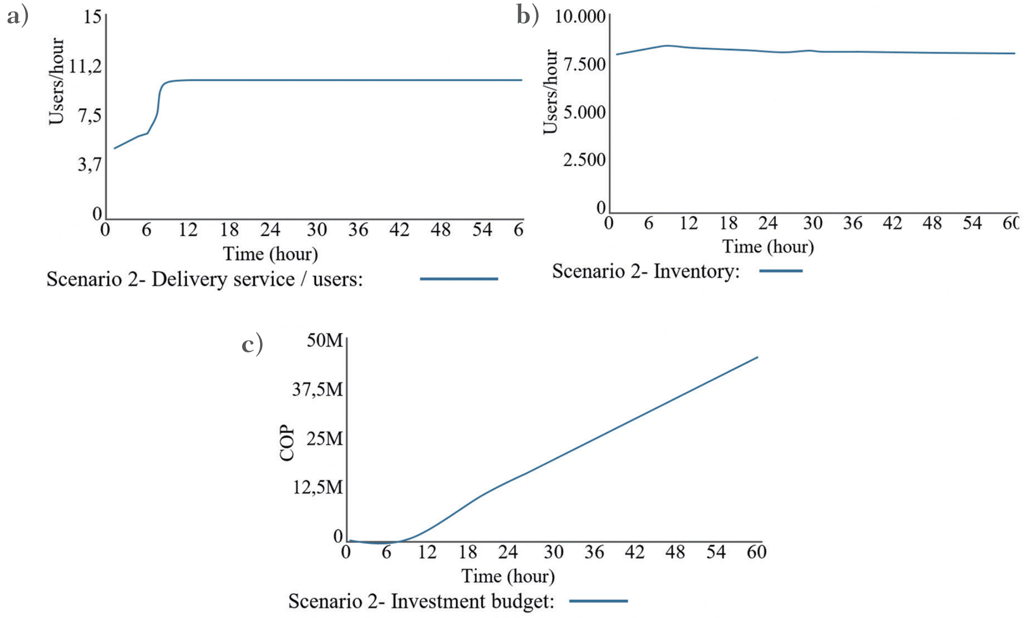


Figure 7. Results from Scenario 2 a) The rate of entry by domiciles - delivery service,
b) The inventory outputs the products sold, and c) the investment budget.
Figura 7. Resultados del Escenario 2 a) La tasa de entrada por domicilios - servicio de entrega,
b) Las salidas de inventario de los productos vendidos, y c) el presupuesto de inversión.



4. CONCLUSIONS AND FUTURE WORK

After analyzing the results, it is possible to affirm that the improved policies have a positive effect on the entire system. This improvement allows the results to be brought closer to the objective of reducing the entry of people and streamlining the service to avoid or reduce the increase in users in the establishment. Therefore, the risk of contagion and number of people sickened by Covid-19 is reduced. In addition, as shown, the investment budget is growing and improvements can be made in the provision of the service without deteriorating it and while taking care of the health of those who come and work at the site. According to the analysis and development of the experimental design, it was possible to demonstrate, through the simulation described, that the policies proposed in the scenarios allow a significant decrease in the income and transmission of the contagion, reducing service times per bill. As a consequence, the workload is decreased, which increases customer satisfaction.

This work turns out to be essential in terms of organizational needs, since Covid-19 revealed the need to make changes in the processes used in the pharmaceutical services and health sector. For the development and success of these changes, it is necessary to involve the working personnel who contribute to the processes and services in the pharmaceutical services. Thus, it is important to generate responsibility and leadership in the health care of the people who make use of the system and the community in general.

In times of pandemic, the evolution of digital technologies and referring to what is stated in this work would be of great help to streamline and change processes that may be obsolete in the digital age. The use of technological tools, as shown, makes it possible to apply improvements, such as digital billing, and thus, reduce variables, such as crowding and subsequent contagion of users. The factors above would help reduce the deterioration of public health in the country. Finally, for the system to reach an optimal service according to the simulation carried out, it is necessary to increase the number of customers per address, and the electronic invoicing must be greater than 100 invoices/hour.

These factors further reduce exposure to the virus and therefore, infections by Covid-19. In addition, the organization that adopts these approaches will improve their position in the pharmaceutical and health sector without the need to make a high monetary investment. It is important to note that employees will not be overloaded with their work, since the workload will be considerably reduced, which will reduce service and billing times.

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