GALILEO: A Georeferenced System Proposed for Emergency Services' Population Control*

GALILEO: un sistema georreferenciado propuesto para el control poblacional en centros de urgencias

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Abstract

Introduction: Overpopulation in emergency services is a problem that can be observed worldwide, and although it has been addressed from different disciplines and perspectives, it still afflicts citizens who are subject to long waiting lists before being attended. *Objective:* The work here describes the design, development and the first validation of a Web and Mobile georeferenced crowd system for the city of Bogotá, Colombia, oriented to inform and empower the citizen on the population status of the emergency services found in the city. *Materials and Method:* In this document, we present the architecture, design, and features of the GALILEO System, with results regarding the first validation with citizens of Bogotá, to capture the acceptance and perceived impact of this type of solution in the context in which the System is proposed to function. *Results and Discussion:* Although GALILEO has not yet been massively implemented in the context for which it is proposed, the results presented here allow us to explore how Information and Communication Technologies (ICT) can be proposed to solve complex social problems, particularly considering the role of the citizen as a source and receiver of information.

Keywords: Social computing, emergency services, crowd computing, pervasive computing, georeferenced technologies.

Resumen

Introducción: La saturación y sobrepoblación en los centros de urgencias es un problema que se presenta a nivel global y, aunque se ha abordado desde diferentes disciplinas y perspectivas, todavía afecta a ciudadanos que están sujetos a largas listas de espera para ser atendidos. *Objetivo:* Este trabajo describe el diseño, desarrollo y la primera validación de un sistema georreferenciado, social y centrado en el usuario: Web y Móvil; orientado a informar y capacitar a ciudadanos de Bogotá, Colombia, sobre el estado de la población de los servicios de emergencia que se encuentran en la ciudad. *Materiales y Método:* En este documento se presenta la arquitectura, el diseño y las características del sistema GALILEO, en conjunto con los resultados obtenidos en una primera validación realizada con ciudadanos de Bogotá, para captar la aceptación y el impacto percibido de este tipo de soluciones en el contexto para el que se propone el sistema. *Resultados y Discusión:* Aunque GALILEO todavía no ha sido implementado masivamente en el contexto para el que se propone, los resultados aquí obtenidos permiten explorar cómo las Tecnologías de Información y Comunicaciones (TIC) pueden ser propuestas para dar solución a problemas sociales complejos, considerando en particular el rol del ciudadano como fuente y receptor de información.

Palabras clave: computación social, centros de urgencias, computación para multitudes, computación móvil, tecnologías georreferenciadas.

Introduction

A problem in emergency services and trauma centers arises due to the lack of population control and the insufficient management of human and physical resources. Although this problem occurs worldwide, it is a daily issue for a large portion of the population in Bogotá, Colombia, which is generally uninformed about the status of emergency services. As a result, the citizen is exposed to long waiting times before being evaluated by a specialized physician. Moreover, a lack of knowledge of the population status of the emergency room in advance, increases the chances of visiting a crowded center, jeopardizing the system, or worse, a risk of not finding the necessary medical resources.

Technological progress in the design and development of new technologies, emphasized in population control, is evident in various research fields. Nevertheless, within the Colombian clinical context, this progress has been slow, since there are no systems to inform and monitor the population status of urgency centers. The Colombian National Health System regulates every health institution to benefit all citizens. Regrettably, in Bogotá, the lack of control over the high population density in emergency services is jeopardized by these strategies, since hospitals do not have the capacity to house and attend all cases that arrive. We believe that this problem arises due to a lack of concrete updated information on the population status in emergency services, offering a context in which the citizen acts without information to make decisions.

Given this problem, it is interesting to pilot and execute a technological solution to reduce the lack of information according to population density in emergency services, while empowering the citizenry with information about their status. Furthermore, the validation of this solution with Colombian citizens, as described here, is attractive and innovative.

This document presents the results obtained after a group of citizens interacted with a Web and Mobile application, which was developed to inform the population about the status of emergency services in Bogotá, Colombia. The aim was to study the perceived impact of the designed solution, towards population control in a sensitive scenario, namely, the clinical context. Results are gathered with User Experience Design (UXD) lens.

This paper is organized as follows. In the next section presents the academic background studied and considered for this project; followed by a section which describes the solution designed and developed. Later, the experimental phase is exposed and the results are presented and analyzed. In the final section, the limitations corresponding to the study are

described and discussed, ending with respective statements of the conclusions and future work inspired by this research.

Academic Background

Globally, several studies from various disciplines have sought to understand, for example, the critical points of the patient care process in emergency services and the way in which physical and human resources should be articulated to optimize the attention that is provided.

Basler, for example, conducted a simulation and optimization study in an emergency room in Chile to find the best possible combination of human and physical resources for a scenario of 40 % population expansion [1]. The aim was to search for the proper combination that enabled the emergency room to operate with the same response times [1]. Through his study and the proposed optimization model, the author demonstrated a significant improvement in the studied process, based on three of the four proposed objectives that showed time reduction [1].

Weng *et al*. performed a study in Taiwan, which focused on the simulation of emergency room systems while using the National Department Overcrowding Scale (NDOS) [2]. From their work, and the simulation of two operational strategies for population decrease in emergency services, the authors concluded that it is possible to achieve overcrowding reductions, as long as there is an intervention in the inflow and wait flows in emergency services [2].

Using a similar approach, García *et al*. performed a simulation to reduce wait times for emergency services at the Mercy Hospital of Florida [3]. In the study, using a proposed quick attention queue for patients, modeling scenarios with and without the intervention, they found a reduction in wait times of 25 % using the proposed rapid attention queue [3]. The authors concluded their study by recommending the efficient distribution of both physical and human resources with the modeled rapid care queue, which suggested to the hospital not to accept patients unless beds were available for patient care [3].

Along the same lines, Khurma *et al*. conducted a study to model, simulate, and ultimately reduce wait times for patients in emergency departments (emergency services) in Canadian hospitals [4]. This proposal was to study the process from the perspective not of the

hospital system but of the patient. Making use of lean tools and techniques, the authors were able to understand the current state of the process and develop corresponding improvements, through the identification of bottlenecks and activities to prioritize [4]. Based on these results, the authors drew interesting conclusions, including a proposal to reduce the time allocated to hospital triage, in addition to the need to inform patients to reduce travel times to emergency services [4].

In another study, Baesler *et al*. designed a simulation model for a private hospital in Chile to estimate the maximum population increase that could be supported in the hospital [5]. Using the patient's time in the room as a variable, the authors measured the amount of physical and human resources required, finding in the particular case of this hospital that the optimal scenario involved four full-time doctors and a part-time doctor attending at the same time [5].

Finally, Wong *et al*. developed a simulation model of discrete events, seeking to emulate the 24-hour service of an emergency and trauma center in Hong Kong [6]. From their study, the authors found that by reducing the waiting time for patients with mild trauma between the first and second medical care, a significant improvement was achieved regarding time reduction [6]. The authors also concluded that their model was favorable in predicting physical and human resource requirements [6].

In the clinical context, no studies or technologies have yet been found that fulfill the purpose of the solution presented and documented here. This work presents GALILEO, as a disruptive alternative whose design and hybrid articulation empower the citizenship to make effective decisions when attending an emergency center. This helps to reduce, in an informed context and through the citizens, the overpopulation in emergency services in the city of Bogotá.

Designed Solution

After studying and understanding behavior and population management in Colombian emergency services, we observed the absence of crowd control in the Colombian clinical context. To achieve this, the design, development and later deployment of an application (Web and Mobile), was performed to inform citizens about the population status of emergency services in the city of Bogotá, Colombia.

The purpose of the IT solution we present is to let the citizens be who transversely consult the information for each emergency room and, likewise, provide it. This is achieved on a case-by-case basis for each emergency room, allowing citizens to grade locations and give their opinion on the number of patients present in the center.

Additionally, the application allows the use of comments to support the information that each user can obtain for various emergency services. Complementarily, it offers visualization of the shortest route, so that the citizen can make the final decision about which clinical center to visit, considering factors of distance and population.

Based on the above background, GALILEO has implemented seven core functionalities:

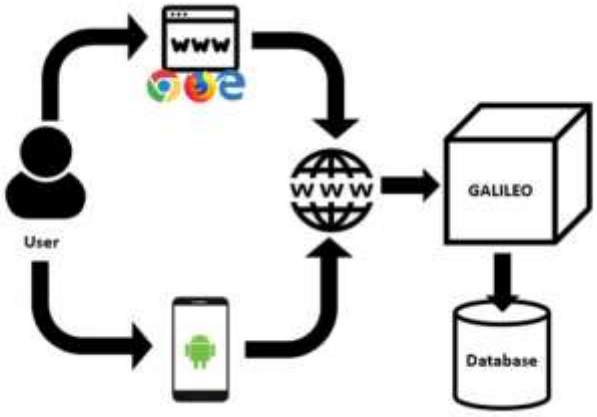
1. Access to hospital information: Determines access and visualization of information for a selected hospital.
2. Grade population status: Allows the user to grade the population status of the selected hospital.
3. Comment: Allows the citizen to comment on a selected hospital.
4. Visualize comments: Allows the user to view comments made by citizens who have visited the selected hospital.
5. Visualize the shortest route: Allows the user to visualize the shortest route from the citizen's geolocated point to the selected hospital.
6. "Contact Us" Option: Functionality for sharing complaints and suggestions from users.
7. Tutorials: Option that shows tutorials on the use of GALILEO.

The functionalities are the same for both versions (Web and Mobile), except for the last two functionalities, which are not incorporated into the Mobile version.

Architectural Overview

In this section, GALILEO's architecture is presented, designed and articulated to respond functionally to the needs described in previous sections [7].

Figure 1. Context diagram



Source: author's own elaboration

As seen in figure 1, the constructed application has a hybrid structure (Web and Mobile), with two versions designed and centered on the user. As observed, the interaction between versions is centralized in a common relational database, which is accessed in an MVC scheme in the Web version, and through Web Services in the Mobile version.

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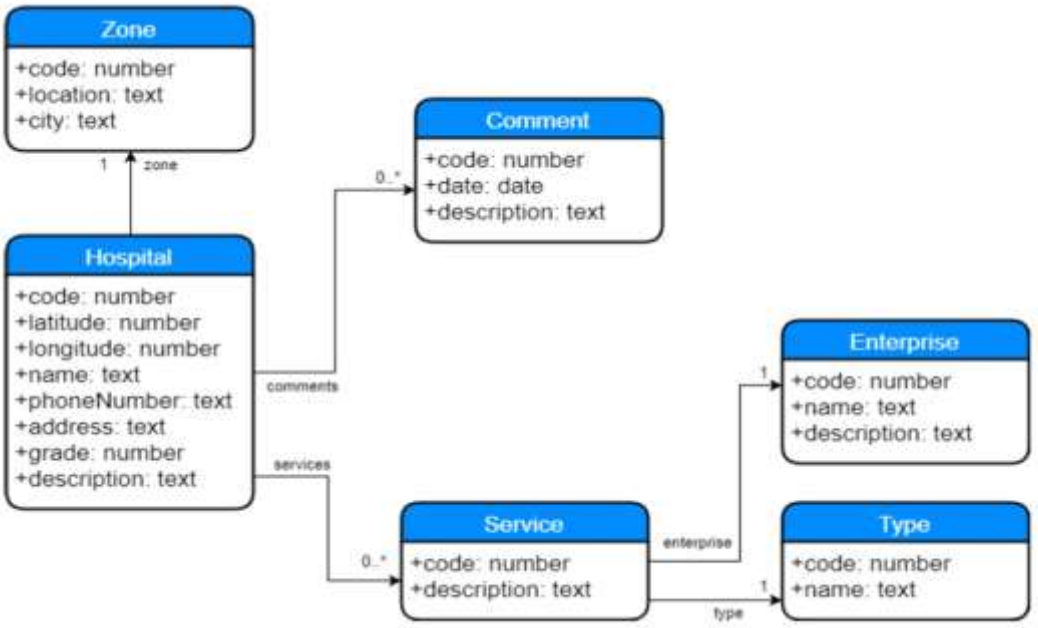
Figure 2. Logic context: Entities diagram



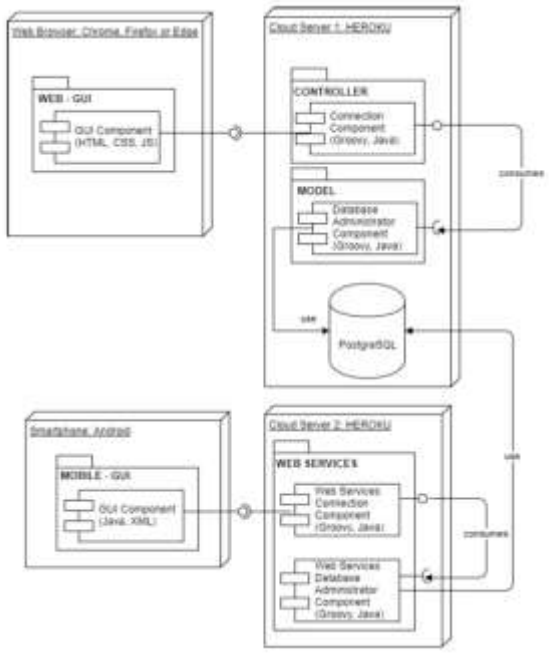
Source: author's own elaboration

Figure 2 shows the Entities Diagram, which corresponds to the logic abstracted from the context. As observed, there are a total of six entities: hospital, zone, comment, service, enterprise, and type. Each hospital has comments, a zone, and possesses a variety of services, each of them with a type and health enterprise that is responsible for it.

Finally, figure 3 shows the deployment, packages, and components associated with the two versions that correspond to GALILEO as a system, presenting the technologies that were used for this pilot, which are detailed in the next section. As illustrated, there were two Cloud Servers [11] for production deployment and a PostgreSQL [12] relational database for data centralization.

The system's analysis and design led to the results presented in experimental phase section, which are later evaluated to obtain the results documented in Results and Analysis section.

Figure 3. System's detailed structure



Source: author's own elaboration

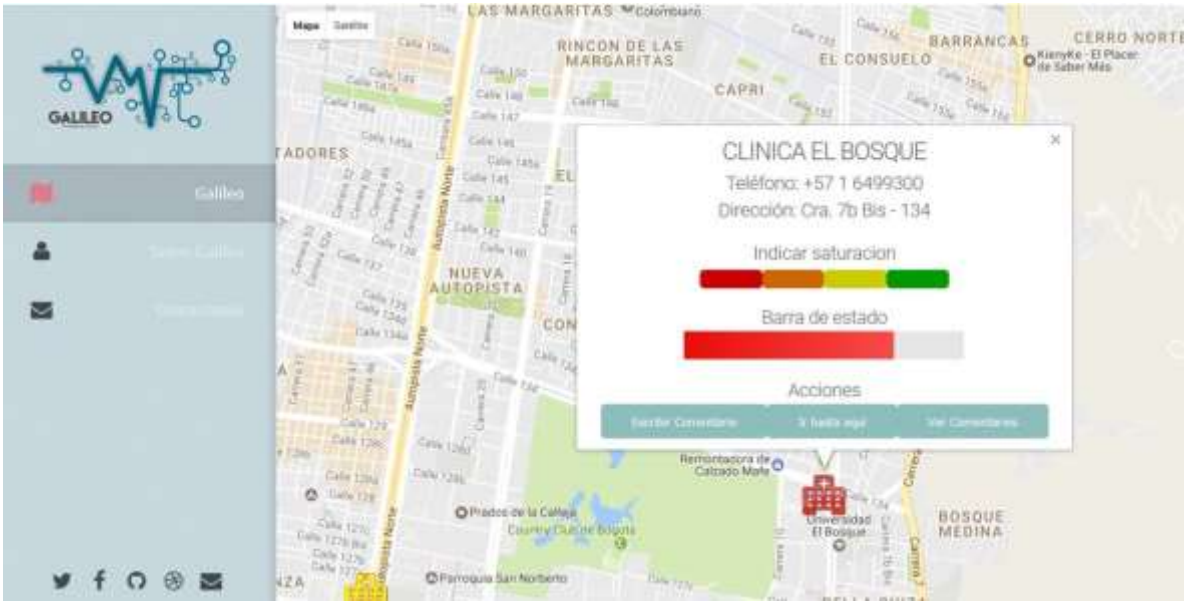
GALILEO: Web version

As seen below in figure 4, the citizen opens GALILEO and is provided with Bogotá's map, its hospitals, and the citizen's current location. The hospitals are colored according to their current population status: green (not crowded), yellow (moderately crowded) and red (crowded). These colors are defined by how citizens have recently graded the hospitals.

Figure 4. Web version: Entrance view

Source: author's own elaboration

Figure 5. Web version: Hospital information and offered actions

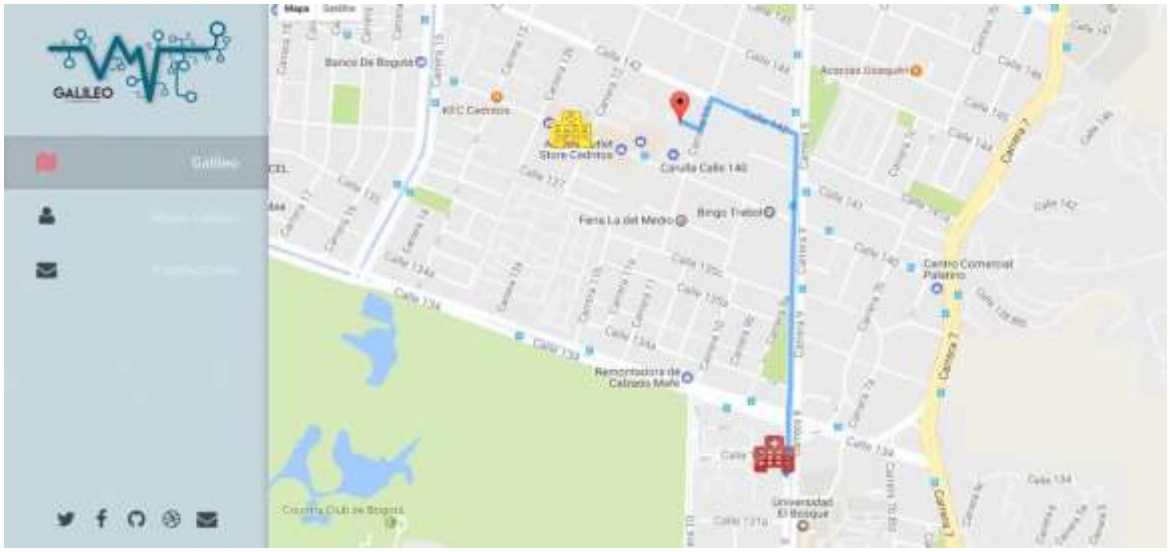


Source: author's own elaboration

Once emergency services are displayed, the citizen can select a service to visualize its information (see figure 5). A window of actions is offered, allowing the citizen to grade the hospital, write or view comments and visualize the shortest route from his/her current position to this hospital (see figure 6). This interface should thus provide sufficient information to the citizen for his/her decision about which hospital and emergency center to visit.

To lend information integrity to the System through this Web version, GALILEO restricts hospital grading and commenting to citizens currently located in its emergency room. This restriction aims to guarantee truth in the process.

Figure 6. Web version: Shortest route visualization

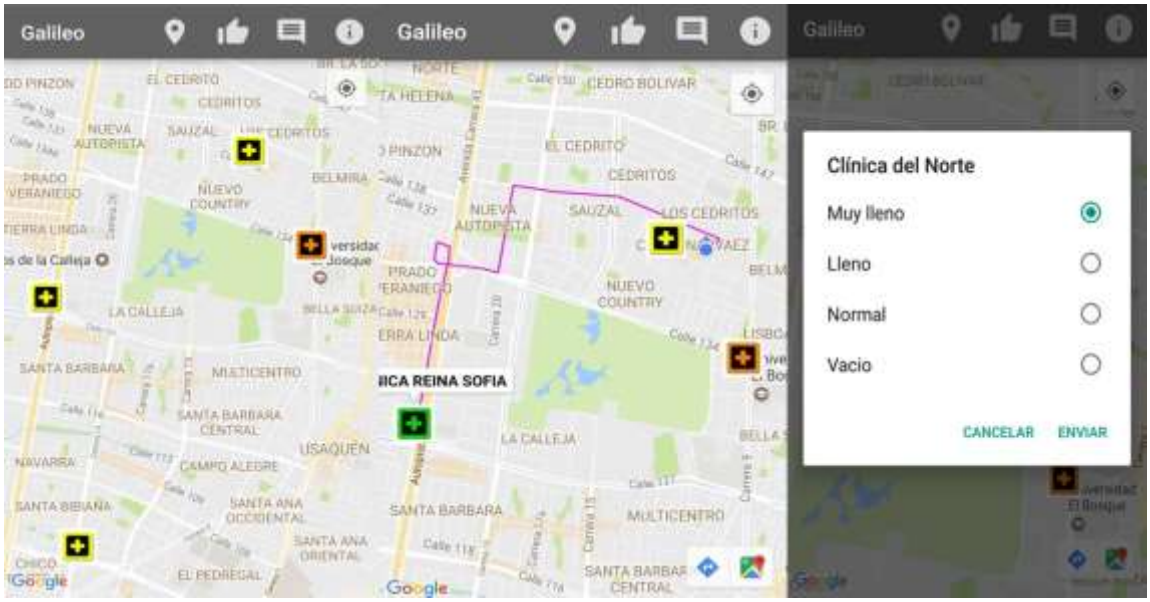


Source: author's own elaboration

GALILEO: Mobile Version

As seen below in figure 7, for this version and the Web version, the citizen initially receives a screen that offers Bogotá's map, its hospitals, and the current citizen's location. As with the Web version, hospitals are colored due to their current population status: green (not crowded), yellow (moderately crowded) and red (crowded). Colors are defined by how citizens have recently graded the hospitals.

Figure 7. Mobile version: Designed screens (main, shortest route & hospital rating)



Source: author's own elaboration

Once the hospitals are displayed, the citizen may select one and visualize its information and the shortest route from the user's location. Likewise, and similar to the Web version, the citizen may write or view comments about a selected hospital and grade it according to its population status. This offers the user sufficient information to decide which hospital and emergency center to access. Finally, the citizen can visualize a hospital's information, which includes its address, phone number and, according to current citizens' perspectives, its population status.

Experimental Phase

In this section, we address the experimental design that corresponds to the software's validation. Further, the objective population and used technologies are described, followed by the experimental design applied and the variables and indices considered.

Sample Population

To validate the solution's functions after completing its development and subsequent deployment, we gathered individuals who satisfactorily responded to the following characteristics:

1. Gender: Male or Female.
2. Technological Familiarity: Middle or High.
3. Physical or Cognitive Disabilities: None.

A total number of 50 users (46 men, four women), with an average age of 25 years, participated actively in the solution's validation. For this study, the number of users who interacted with the solution corresponds to a significant sample for the validation of variables and designed indices, following the recommendations of Nielsen for the selection of the sample population's size [13]. The participating population interacted with both versions, answering quantitative and qualitative evaluations, according to the variables and indices defined for this phase (see Experimental Design section).

Experimentation: Technologies Used

The following technologies were used to conduct the experimental phase of this study. These technologies and tools were selected to meet the needs that arose in this project:

1. GALILEO-Web Version: Web version specifically designed and developed to meet the needs of this project. This tool provides the mechanism to evaluate and validate data using a crowdsourcing approach, seeking to address the existing lack of information for emergency services in Bogotá, Colombia (see Design Solution section), and to reduce overcrowding scenarios.
2. GALILEO-Mobile Version: Mobile version specifically designed and developed to meet the needs of this project. This tool provides a mechanism to evaluate and validate data using a crowdsourcing approach, seeking to attack the existing lack of information about emergency services in Bogotá, Colombia (see Design Solution section), and to reduce overcrowding scenarios.
3. Google Forms: Tool used to capture quantitative and qualitative information, which is required to evaluate indices and variables proposed for the project.
4. Microsoft Excel v2016: Tool used to tabulate the results obtained through the experimental phase of this project.

Both versions of GALILEO were compared to evaluate the impact generated by a technological approach, quantifying whether both could be useful in informing the citizen.

The main purpose of this comparison is not to directly reduce the existing overpopulation but to study the impact of a tool designed to interactively report on the population status in hospitals, specifically in emergency services.

Experimental Design

The citizen signed a consent document to participate in the study and allow us to make use of the gathered data.

Then, he/she interacted for one hour with both versions of GALILEO and responded afterwards to two assessments for each: a quantitative assessment and a qualitative

assessment. The quantitative assessment corresponded to interaction time measurements in seconds, according to each functionality's access and use (see Considered Variables and Designed Indices sections). In the qualitative assessment for each version, the citizen gave his/her perception of the solution and whether he/she appreciated its role in helping solve overpopulation in Bogotá's emergency and trauma rooms.

Once the assessment results were obtained, we performed calculations and analysis on the corresponding indices to proceed with the respective project's conclusions and answer the previously stated research query (see Introduction). The functionalities that were assessed are described below:

1. F1 (Access Hospital's Information): This functionality was designed to allow the user to visualize information for a selected Hospital.
2. F2 (Access to Grade Hospital's Population State): This functionality was designed to allow the citizen to grade a Hospital according to its population state.
3. F3 (Access to Comment about a Hospital): This functionality was designed to allow the citizen Access to comment on a selected Hospital.
4. F4 (Access Previous Comments): This functionality was designed to allow the citizen to visualize the comments of other citizens on a selected Hospital of interest.
5. F5 (Access to Visualize the Shortest Route): Functionality designed to allow the citizen to view the shortest route from his/her location to a selected Hospital of interest.
6. F6 (Access the "Contact Us" Option): Functionality designed to allow the citizen to share complaints and suggestions.
7. F7 (Access to Tutorials): Functionality designed to help the user understand both versions of GALILEO.

It is important to highlight that the last two functionalities are only available through the Web version.

Considered Variables

To perform a complete analysis of the results obtained, the following variables and indices were considered and designed as experimental tools for this study:

1. Usability (V1): This variable is used to understand how user-friendly both versions are. We defined an integer numerical scale from one to five to capture and understand how easy-to-use the citizens found each version of the solution.
2. Usefulness (V2): Variable approached with a qualitative survey by asking the citizens how useful they considered GALILEO as a solution for the context's needs.
3. Time Access (V3): Quantitative variable, which corresponds to the time (in seconds) required by a citizen to find and use each of the proposed functions.

Designed Indices

To perform a complete analysis of the obtained results, the following variables and indices were considered and designed as experimental tools for this study:

1. Global Usability Index (I1): Evaluates the global usability level, which is built with the average of data obtained with variable V1, per version. See equation (1).

$$I1 = \frac{(\sum_{i=0}^{n} V1_i)}{n} \quad (1)$$

2. Global Usefulness Index (I2): Built with the average of data obtained with variable V2, per version. See equation (2).

$$I2 = \frac{(\sum_{i=0}^{n} V2_i)}{n} \quad (2)$$

3. Global Access Time Index (I3): Built with the average of data obtained with variable V3, per version. See equation (3).

$$I3 = \frac{(\sum_{i=0}^{n} V3_i)}{n} \quad (3)$$

Finally, an impact index was defined to observe how the intervention of both versions of GALILEO responded and affected the involved context: emergency and trauma rooms.

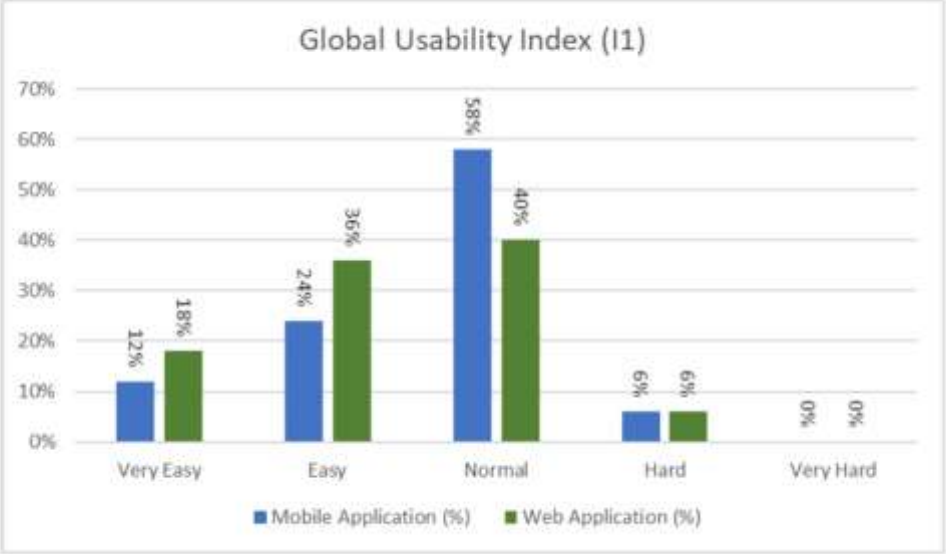
4. Impact Index (I4): Defined as the main index for this project, which is built with the three previous indices. It is considered positive if the predicate is true. See equation (4).

$$I4 = ((I1 \geq 3.5) \vee (I2 \geq 3.5)) \wedge (I3 \leq 10s) \quad (4)$$

Results and Analysis

The results presented below are organized based on the variables and indices considered and designed for the experimental phase of this study.

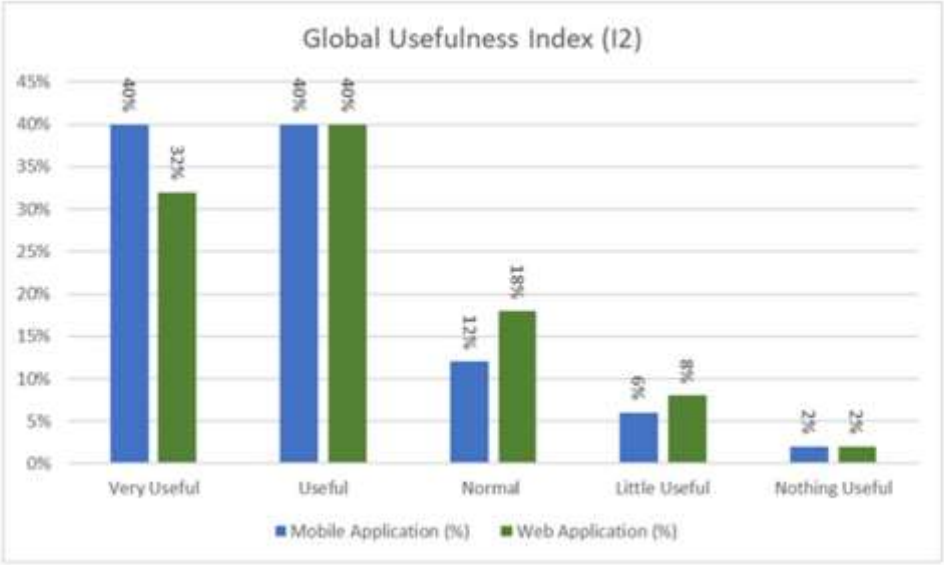
Figure 8. Index I1: Results



Source: author's own elaboration

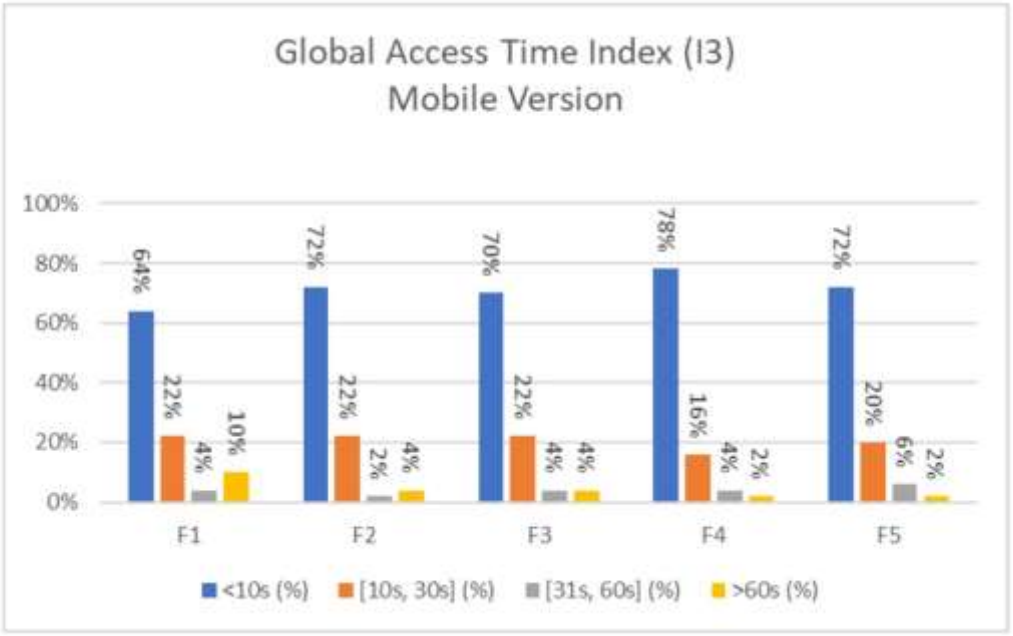
Figure 8 shows the results obtained after every user interacted with each version. The graph represents index I1, and as seen, there is a positive average for the items on the scale: "Very Easy", "Easy" and "Normal".

Figure 9. Index I2: Results



Source: author's own elaboration

Figure 10. Global access time index: Mobile version

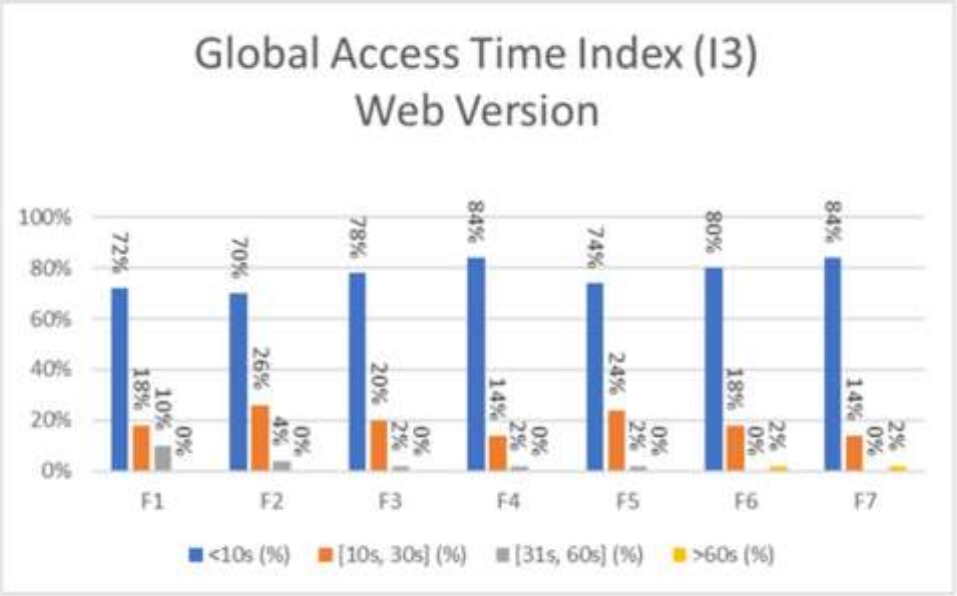


Source: author's own elaboration

Figure 9 shows the results of the users' interaction with both versions, plotting results that correspond to Index I2, per version. As seen, there is a positive average for the items on the scale: "Very Easy", "Easy" and "Normal".

For Global Access Time Index – I3, the results obtained are displayed in seconds, according to the time each user took to access specific functionalities of the solution. Figure 10 shows the proportion of users that was above and below the average, based on results corresponding to the Mobile version of the system.

Figure 11. Global access time index: Web Version



Source: author's own elaboration

Table 1. Impact index's measurement

Boolean Statement	Boolean Validation
$S1 = (I1 \geq 3{,}5)$	$S1 = (3{,}54 \geq 3{,}5) = True$
$S2 = (I2 \geq 3{,}5)$	$S2 = (4{,}01 \geq 3{,}5) = True$
$S3 = (I3 \leq 10s)$	$S3 = (8{,}09s \leq 10s) = True$
$I4 = (S1 \vee S2) \wedge S3$	$I4 = (True \vee True) \wedge True = \mathbf{True}$

Source: author's own elaboration

In the same way, in figure 11, the results refer to the access time (in seconds) for each functionality of the Web version. As seen, most users took less than 10 seconds to access and use each application functionality, for both versions.

Finally, the Impact Index – I4, was calculated using the results for other indices. As shown in table 1, according to equation (4), a favorable result is obtained, given that the predicate proposed for this index returns true.

Because Impact Index – I4 was affirmative, it is argued that for the citizens and according to the sample population selected, the tool has a positive impact within the context of the study.

Conclusions and Future Work

First, we conclude that GALILEO fulfills the main objective of creating an interactive application to provide information about the population status of emergency services. This is based on the results of the citizens' interaction with both versions, Web and Mobile, considering the variables and indices designed for this project (see Results and Analysis section).

However, we conclude that it is possible that citizens can be informed by using new technologies such as GALILEO, centered in a specific context of interest (population control). In addition, the solution is perceived by the sample population as a useful, high impact, easy-to-use technology [72 % to 80 % of the sample population, according to figure 9]. This conclusion is based on results that correspond to the designed indices (see Results and Analysis section). Other interesting results include the access time for each functionality: users spent less than ten seconds, which shows how intuitive each version was for them. GALILEO as a pilot project was a success and was considered an interesting, user-friendly and innovative technology, which was well received by the citizens who helped validate its functionalities and usability.

Following this study, and having concluded the GALILEO pilot, a wide range of opportunities for future work are now opened, considering the incorporation of other aspects that meet needs centered around the same context. This study only evaluates the impact of introducing technologies in a medical context through tools such as GALILEO. A

future task may be to evaluate the use of both versions, Web and Mobile, within the proposed context: emergency centers. The latter can be used to measure the corresponding effectiveness of the solution, by identifying and further accessing possible pivotal scenarios.

In summary, we consider it necessary to promote the massive use of GALILEO to achieve a global massification to detect opportunities and risks and establish criteria of success for these Web and Mobile solutions that are immersed in a clinical context, more specifically, in emergency services.

Acknowledgment

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References

[1] F. F. Baesler, "Multiobjective emergency room capacity planning using simulation and response surface methodology," in *2016 Proc. Winter Simul. Conf., WSC '16*. IEEE Press, Piscataway, NJ, USA, pp. 3706–3707.

[2] S. Weng, P. Huang, W. Chang, L. Wang, and C. Chang, "The impact of operations strategies for emergency room in Taiwan," in *2013 Proc. Symp. Theory Model. Simul. DEVS Integrat. M&S Symp., DEVS 13*. Society for Computer Simulation International, San Diego, CA, USA, Art. no. 18.

[3] M. L. García, M. A. Centeno, C. Rivera, and N. DeCario, "Reducing time in an emergency room via a fast-track," in *1995 Proc. 27th Conf. Winter Simul., WSC '95*. IEEE Computer Society, Washington, DC, USA, pp. 1048–1053. doi: 10.1109/WSC.1995.478898

[4] N. Khurma, G. M. Bacioiu, and Z. J. Pasek, "Simulation-based verification of Lean improvement for emergency room process," in *1995 Proc. 40th Conf. Winter Simul., WSC '08*. Miami, Florida, USA, pp. 1490–1499. doi: 10.1109/WSC.2008.4736229

[5] F. F. Baesler, H. E. Jahnsen, and M. DaCosta, "Emergency departments I: The use of simulation and design of experiments for estimating maximum capacity in an emergency room," in *2003 Proc. 35th Conf. Winter Simul. Driving Innovat., WSC '03*. New Orleans, LA, USA, pp. 1903–1906. doi: 10.1109/WSC.2003.1261651

[6] Z. S. Wong, A. C. Lit, S. Leung, K. Tsui, and K. Chin, "A discrete-event simulation study for emergency room capacity management in a Hong Kong hospital," in *2016 Proc. 2016 Winter*

Simul. Conf., WSC '16. IEEE Press, Piscataway, NJ, USA, pp. 1970–1981. doi: 10.1109/WSC.2016.7822242

[7] N. Rozanski and E. Woods, *Software Systems Architecture: Working with Stakeholders Using Viewpoints and Perspectives*. Addison-Wesley Professional, 2005.

[8] K. Malone and J. Griffith, "A case study in the use of Groovy and Grails," in *2012 Proc. 27th Annu. ACM Symp. Appl. Comput., SAC '12*. New York, NY, USA: ACM, pp. 1254–1255. doi: 10.1145/2245276.2231973

[9] Grails, *A powerful Groovy-based web application framework for the JVM built on top of Spring Boot*, Grails Framework [Online]. Available: https://grails.org/

[10] "Groovy/Grails Tool Suite™ will be available from Pivotal for a limited time." Accesed on: Dec. 8, 2017. Available: https://spring.io/tools/ggts

[11] G. Irizarry, "Beginning native Android apps," in *2015 Proc. SIGGRAPH 2015 Studio, SIGGRAPH '15*. New York, NY, USA: ACM, Art. no. 34.

[12] J. Solheim, "Web apps in the computer science curriculum: A guide using Heroku, Java servlets, and Postgres," *J. Comput. Sci. Coll.*, vol. 30, no. 5, pp. 126–133, May. 2015.

[13] R. Herzog, "PostgreSQL: The Linux of databases," *Linux J.*, vol. 1998, no. 46es, Art. no. 1, Feb. 1998.