Progressive Web App for Medical Consultation

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ABSTRACT: *Health systems across countries have witnessed big investment and various health centers both public and private are being developed which also have problems. There are instances where the lack of organization and them is use of the available technological resources have caused a poor flow of information within the health centres causing problems of internal mobility towards the patients. Besides, the technological developments in the health sector with e-Health being one of these trends, which promotes the application and use of Information Technology in medical processes in all its levels, providing concepts and good practices that promote the implementation of new technological trends focused on this field. Thus the current work highlights the design of a methodological proposal which allows automating processes such as the delivery of information and internal mobility of patients, key aspects of this proposal, applied to a case study at the Integral Health Centre Assistant Matriz Norte (CISA). To achieve it we have developed a Progressive Web App with the Ionic Framework which allows to deliver all the necessary information to the patient regarding the automated processes, and at the same time the collection and validation of the results will be carried out based on the times of internal mobilization and satisfaction of the patients. In the experimentation process, the results are collected and analyzed and contrasted with the CISA absenteeism rates in order to reduce them.*

Keywords: Absenteeism, E-health, Mobility, Progressive Web Apps, Cloud Computing, Ionic Framework

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1. Introduction

Due to the massification of both patients and specialties in health centres in Ecuador, given the lack of information in an adequate and timely manner, whether due to insufficient physical space, untrained personnel, or deficient use of technological resources, mobility and accessibility problems are generated for patients within these centres, which in most cases generates absenteeism to planned medical consultations with an average rate of 12% [6].

This problem lies in the lack of internal organization and use of available resources, especially in such a technologically advanced society tends to use old media, generating a poor flow of information within health centres in Ecuador, that causes discontent with patients and deprives equitable access to both infrastructure and internal information, this is something that must be taken into account in community establishments, based on what the National Development Plan dictates [13].

This proposal aims to optimize technological resources to provide improvements in patient care regarding mobility and accessibility problems that exist within health centres in Ecuador, it will be applied to a case study with the aim of validating it. For this, it is proposed to design a portable progressive web application (Progressive Web App - PWA), which uses the geolocation of mobile devices; This technology will provide access to patients and greater usability which will help to have a greater range of patients without a high level of digital literacy.

The main contributions of our paper include: (1) to determine the associated concepts in this proposal regarding e-health, absenteeism, mobility, and prototype deployment models.; (2) to determine the appropriate technological infrastructure that the health centre should have for the implementation of this methodological proposal to be developed; (3) to design and develop a progressive web application based on geolocation that allows the evaluation of this research work.

2. Experimental Setup and Methodology

2.1 Health in Ecuador

The Public Health System in Ecuador has improved with the construction of new public facilities and patient care areas, currently having 910 medical centres corresponding to the IESS nationwide. According to data obtained in the web portal of the Ministry of Public Health called GeoSalud (https://geosalud.msp.gob.ec/geovisualizador), which is an application that shows the real-time information regarding geolocation of medical centres and the main information of these, as an aid for the external mobility of patients to easily locate where to go either for emergencies or planned medical appointments.

Just as improvements have been made to the public health system, there has been an increase in the so-called "health production" by the Ministry of Public (MSP) Health as can be seen in Figure 1, denoting the growing demand in medical appointments which is not fully supplied by the number of Public Health Centres in Ecuador.

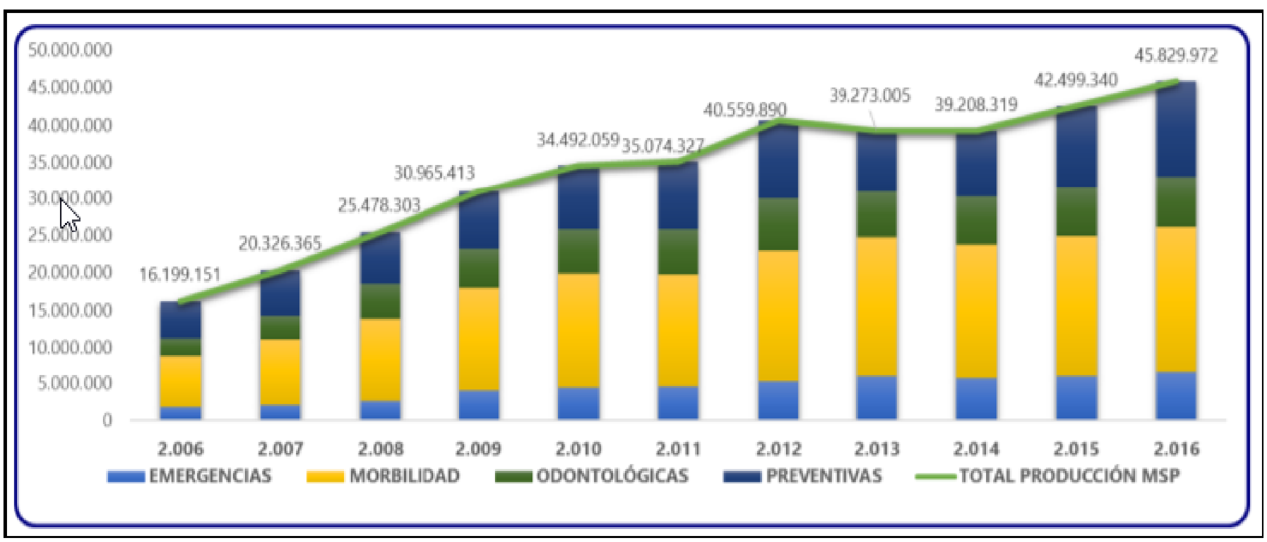

Figure 1. Health production by type of care 2006- 2016 [9]

Given this referral of patients through the "Red Complementaria" which has 489 private health centres according to data from the GeoSalud portal, a problem arises regarding internal mobility in these health centres since most of the patients who are redirected there do not know how to go to the different doctor's offices due to disorganization and lack of available information and especially because of the large number of patients.

2.2. Absenteeism

Absenteeism is a very serious problem that occurs very often in different areas, especially in the labor aspect, in the specific case of this project the absenteeism of patients in medical appointments will be studied. One of the reasons that has been evidenced for this absenteeism to occur is the lack of knowledge and lack of information that is provided to patients in regard to health centres and mobility within them, generating delays and absences among patients to medical appointments [1, 9]. In Ecuador there is a high rate of absenteeism to medical appointments within the health system, which is alarming since this causes losses of resources for the State, which could be used to improve health services and thus benefit to a greater part of the population.

2.3. Mobility

The concept of mobility can be defined as the movement or displacement of a person through a path or route [2], adequate knowledge and the ease that is given to travel in the best way without complications that hinder movement. In the field of health, when talking about internal mobility in the Health centres of Ecuador, reference can be made to the ease that these centres provide to patients and the amount of information necessary to allow a flow of patients in the different areas that are visited in order to attend scheduled medical appointments and thus avoid delays, and therefore absenteeism in them.

2.4. e-Health

Through e-Health, a redefinition of the health centres of the traditional towards digital is sought, with improvements in Information Technology and the optimization of the available resources by these centres, and thus providing better solutions to the health field that benefit the entire participating community.

For the adoption of the basic characteristics of e-Health, [7, 8, 11, 12] allow obtainig an optimal and quality result in the application of the different information technologies to the health field. Therefore, in the present investigation the processes of providing information in a clear and timely manner, and the internal mobility of patients, will be improved, through the following characteristics:

– **Utility:** Through the prototype, patients will be given with a complete guide of information and internal mobility, generating self-sufficiency in these processes.

– **Sustainability:** The application will be designed with the aim that the patient himself uses it without requiring help from CISA personnel, being intuitive and understandable.

– **Accessibility:** To be able to run on the web through a URL or otherwise the QR code shown in strategic points of the CISA, the patient can access the application easily and from any internal location.

– **Adaptability:** By containing essential information regarding CISA in the database and working with a distributed architecture, new functionalities can be implemented, either directly from the core of the application or external, such as consulting medical appointments by the patient and showing the route to doctor’s offices.

– **Open approach to digital development:** Being developed with the Ionic framework it has great flexibility to be in constant updates and has a large community that provides new components and functionalities, in addition to receiving a large number of people from which it can get recommendations for improvement.

– **Personalized:** As there is a large influx of patients, it is necessary to have information from CISA, as well as internal mobility in a fast and timely manner to avoid delays or absenteeism to medical appointments without theneed for a third party.

2.5. Cloud Computing

This technology within e-Health is of great help as it proposes a fast and timely deployment method [4]in any location for users. In addition, by consuming resources remotely, it allows for faster processing speed, thus allowing for more robust applications and better inter-connectivity by being able to use mobile devices as a mean of access to applications deployed in the cloud, thanks to wireless technologies and the ability of these devices to interact in them [3].

Within e-Health, applying cloud computing there are five essential characteristics [4] that must be applied at the time of deployment:

– **Services on demand:** Services must be provided without the need for people to interact.

– **Robust access to the network:** Services must be accessed from anywhere at any time.

– **Availability:** Users can access services simultaneously.

– **Elasticity:** The services must be arranged according to what is required by the health centre.

– **Measured service:** Users, if applicable, will only pay for the services they have used.

In this way, immediate information can be obtained from the health centres for decision-making [5] for both doctors and patients, streamlining the health system and preventing medical negligence many times for using traditional methods in obtaining and generating information.

2.6. Infrastructure

For the design of the application, we will work with a distributed architecture [11] illustrated in Fig 2, where the server part will run REST Web Services to facilitate communication between the relational database implemented in MySQL on a cloud server and the mobile prototype.

This prototype will be a progressive web application (PWA) developed in the Ionic Framework, which works in a hybrid way running through the web consuming Google services for geolocation and map generation.

Given this characteristic of PWA, this technology has been selected as the most suitable for the realization of the prototype because it allows greater agility in the execution and use of it in an environment in which it is necessary to minimize the greatest amount of time to mobilize internally to the doctor's offices to attend medical appointments, since according to data obtained by the company Google, 53% of users close websites that take more than 3 seconds to load their content [14] because the main objective of using mobile devices is to obtain concise and agile information as they are small and easily portable devices.

2.7. System Architecture

To facilitate the use of the application to patients and improve the time of care within the Health Center, the prototype inter-

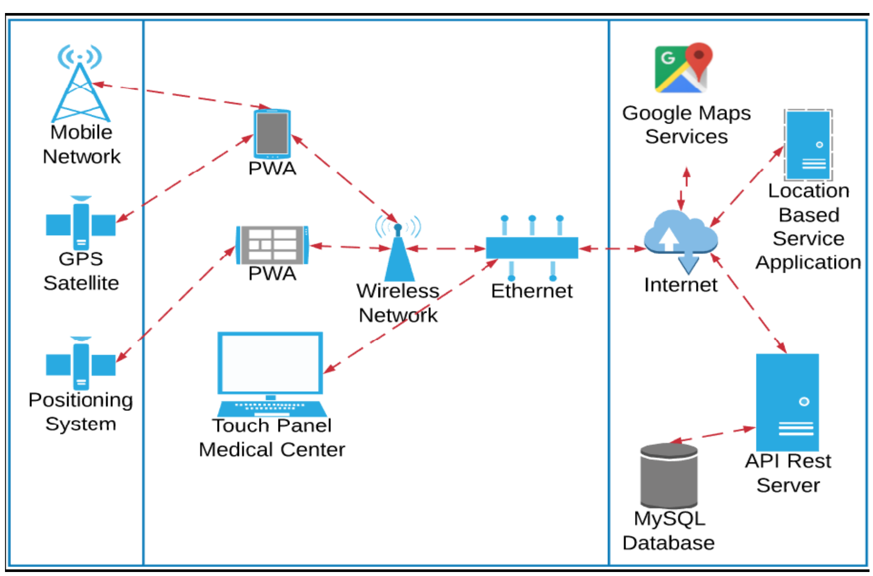

Figure 2. Functionality Network Diagram

face was deployed on a web server to access from any device regardless of the type of connection [15] (Wifi or mobile data) using a URL or a QR code. The data was stored in the cloud and can be accessed through REST services, taking the necessary measures to ensure the security and integrity of the information.

For the design of the architectural diagram (see Fig. 3), the application will work with a distributed architecture [11] where the server part will execute REST Web Services to facilitate communication between the different platforms that will be managed.

The database is on a PasS server, which is implemented in the Google Cloud Platform with a free version for students, which will take over storing the CISA information used for the prototype. This information will be extracted by the backend server which will be developed with the NodeJS language implemented through PaaS on the Microsoft Azure platform, this server will expose REST Web Services so that the prototype that will be developed in Ionic Framework can access the information through the connection to the different REST services created.

The prototype developed in Ionic Framework working on Angular allows access to REST services through an HTTP request in order to display information regarding the proposed deployment model. Finally, for the execution of the maps, the prototype will be connected through the Google Maps API for Ionic to the "Maps" and "Geolocation" services contained therein, validation being necessary through a code obtained in the Google Cloud Platform website.

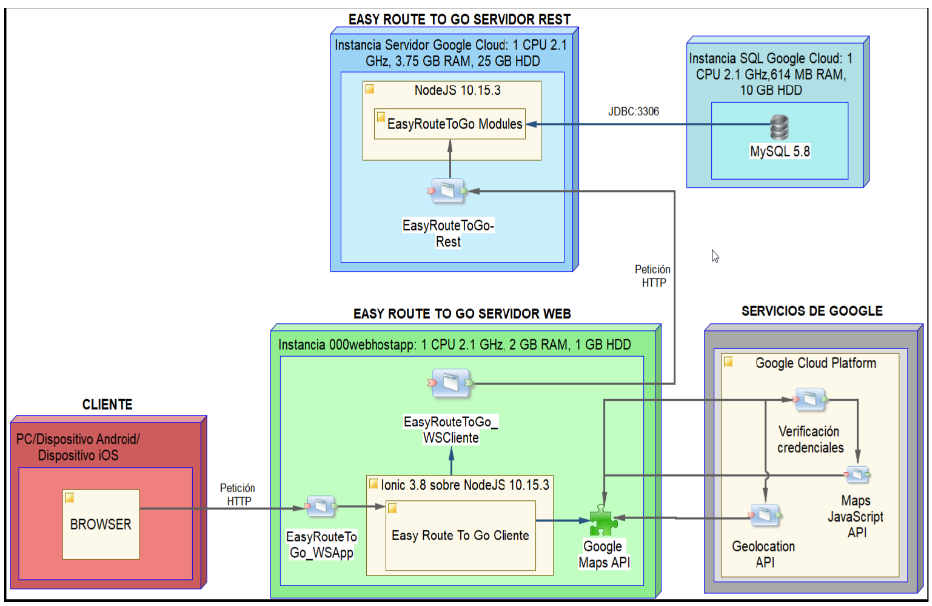

Figure 3. Prototype architecture diagram

2.8. Software Prototype

The development of the prototype gave as a result in autonomy in mobility and greater access to information regarding the medical services provided by the health centre significantly reducing absenteeism and delays in medical appointments.

Because there is a large number of patients with different technological capabilities, the prototype was designed so that it is intuitive and provides clear and concise information, thus having a linear flow (Fig. 4 a-b-c) of information to finally show the routes generated using the API Google Maps based on Java script.

2.9. Route Generation Algorithm

Google Maps provides in its own application as well as in its services the generation of routes, but this model works on a large scale in city streets, but for small places that are only accessed by pedestrians these services do not have an adequate functioning anymore because do not generate routes by not having streets or passages on their maps, so that the present project focuses on generating routes that solve this problem, making reference to a previous study of the researchers [10] in which When using the API tools an algorithm was created that allows the route to be plotted automatically based on a series of manually

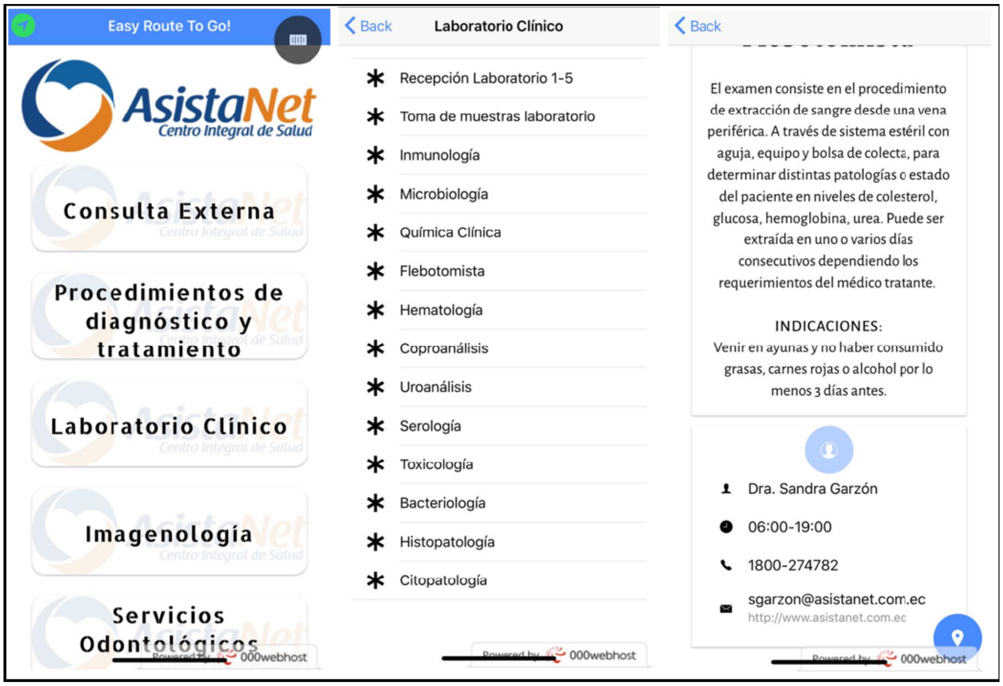

Figure 4. a) Medical areas screen. b) Doctor's offices screen. c) Doctor's offices Information

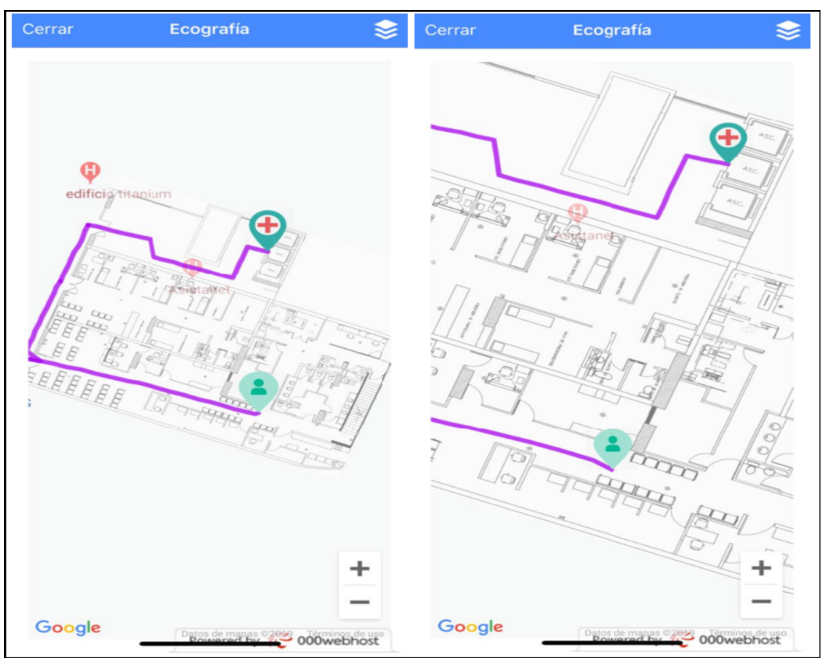

Figure 5. Automatically generated internal routes

mapped points which are part of the internal routes of the health centre (see Fig. 5).

This algorithm is based on the search of the uniform cost taking as a weight of each node the distance with the consecutive node in such a way that the shortest route from the beginning to the destination is found, but this algorithm presented the problem that having the dispersed nodes tended to move away from the end in certain cases, so a heuristic is applied which consists in additionally obtaining the minimum distance between each node with the final node. Therefore, the point closest to the origin has the shortest distance in a straight line to the destination, thus obtaining the most optimal route, which allows to reduce arrival times.

3. Polynomial Regression Method

To analyze the statistical procedure, the polynomial regression method was used, which consists in adding a curvature to the model by introducing new predictors, which are obtained by elevating all or some of the original predictors to different powers.

We start from the linear method:

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i \tag{1}$$

Then a polynomial model of degree *d* is generated from the equation:

$$y_i = \beta_0 + \beta_1 x_i + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots + \beta_d x_{di} + \varepsilon_i \tag{2}$$

This polynomial model is adjusted by linear regression by least squares, where nonlinear models are generated, the mathematical equation is still linear equation with predictors $x_1, x_2, x_3, ..., x_d$, for the different routes the linear and non-linear relationship between the two variables, using a polynomial model of degree 4, which allows predicting routes based on time, initially fits a linear model by least squares specifying the dependent variable (Routes) and predictors (Time) directly.

However, a general matrix of standardized residual errors will be constructed for all routes, to analyze them respectively.

The collection of internal mobilization times was carried out anonymously through the generation of the route from the

	Morning	**Afternoon**	**Night**
Without application	Residual standard error: 0.2627 on 21 degrees of freedom. Multiple R-squared: 0.02929. Adjusted R-squared: -0.1556. F-statistic: 0.1584 on 4 and 21 DF. p-value: 0.957	Residualstandard error: 0.235 on 21 degrees of freedom. Multiple R-squared: 0.119. Adusted R-squared: -0.04884. F-statistic: 0.709 on 4 and 21 DF. p-value: 0.5948	Residualstandard error: 0.1511 on 21 degrees of freedom. Multiple R-squared: 0.06513. AdjustedR-squared: -0.1129. F-statistic: 0.3657 on 4 and 21 DF. p-value: 0.8302
With application	Residual standard error: 0.206 on 21 degrees of freedom. Multiple R-squared: 0.03409. Adjusted R-squared: -0.1499. F-statistic: 0.1853 on 4 and 21 DF. p-value: 0.9434	Residualstandard error: 0.2042 on 21 degrees of freedom. Multiple R-squared: 0.0763. A d - justed R-squared:-0.09964. F-statistic: 0.4337 on 4 and 21 DF. p-value: 0.7827	Residualstandard error: 0.1057 on 21 degrees of freedom. Multiple R-squared: 0.0433. Adjusted R-squared: -0.1389. F-statistic: 0.2376 on 4 and 21 DF. p-value: 0.9139
Residual standard error	Without application – With application: 0.2627>0.206 6.10%	Without application – With application: 0.235>0.2042 3.08%	Without application – With application: 0.1511>0.057 9.41%.

Table 1. Vital signs – doctor’s offices 900

starting point to the destination point in the application, selecting the routes most visited by patients based on the highest number of occurrences, thus obtaining an average of 200 daily samples for each route. For the analysis of the data obtained, the samples of a full month of the following three routes were taken:

	Morning
Whithout	Y=8.517612+0.16876x+0.02074x^2-0.06664x^3+0.10191x^4 application std. Error: 0.5111
With	Y=6.255909+0.06219x+0.15494x^2-0.04253x^3+0.04192x^4 application std. Error: 0.10567
	Afternoon
Without	Y=12.85687-0.16487x+0.25241x^2-0.18441x^3-0.17810x^4 application std. Error:0.23500
With application	Y=8.386415-0.149093x-0.007593x^2-0.205624x^3+0.087959x^4 std. Error:0.204158
	Night
Without application std.	Y=8.27547+0.06024x-0.13381x^2+0.10205x^3+0.03815x^4 Error: 0.15111
With application	Y=6.32902-0.02842x+0.05153x^2+0.01920x^3-0.08235x^4 std. Error: 0.10567

Table 2. Polynomial Regression Polynomials Vital signs – doctor’s offices 900

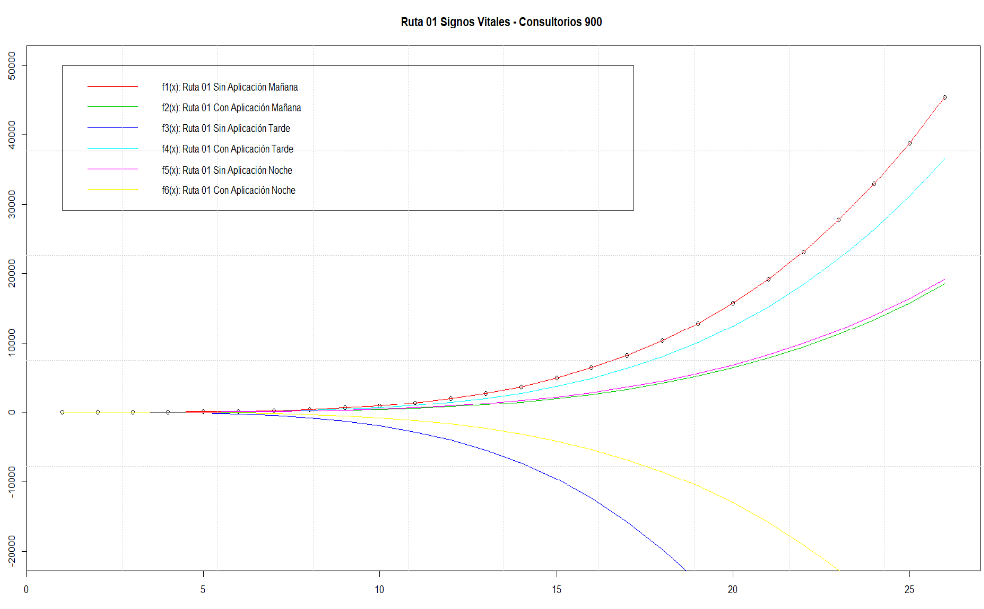

Figure 6. Route 01

	Morning	Afternoon	Night
Without application	Residualstandard error: 0.1978 on 21 degrees of freedom. Multiple R-squared: 0.02346. Adjusted R-squared: -0.1625. F-statistic: 0.1261 on 4 and 21 DF. p-value: 0.9714	Residual standard error: 0.1135 on 21 degrees of freedom. Multiple R-squared: 0.09123. Adjusted R-squared:-0.08187. F-statistic: 0.527 on 4 and 21 DF. p-value: 0.7171	Residualstandard error: 0.3472 on 21 degrees of freedom. Multiple R-squared:0.05435. Adjusted R-squared: -0.1258. F-statistic: 0.3017 on 4 and 21 DF. p-value: 0.8735
With application	Residualstandard error: 0.1433 on 21 degrees of free dom. Multiple R-squared: 0.04496. Adjusted R-squared: -0.137. F-statistic: 0.2471 on 4 and 21 DF. p-value: 0.9082	Residualstandard error: 0.08557 on 21 degrees of freedom. Multiple R-squared: 0.1553. Adjusted R- squared: -0.005629 F-statistic: 0.965 on 4 and 21 DF. p-value: 0.4472	Residualstandard error: 0.2635 on 21 degrees of freedom. Multiple R-squared: 0.0804. Adjusted R-squared: -0.09476. F-statistic: 0.459 on 4 and 21 DF. p-value: 0.9139
Residual standard error	Without application – With application: 0.1978> 0.14335.45%	Without application – With application: 0.1135>0.08557 2.79%	Without application – With application:0.3472>0.2635 8.37%

Table 3. Entrance – Dentristy

	Morning
Whithout	Y=7.57575-0.10183x-0.06419x^2-0.06419x^3+0.06692x^4; application std. Error: 0.19777
With	Y=5.69737-0.02941x-0.02035x^2-0.13685x^3+0.01745x^4; application std. Error: 0.14334
	Afternoon
Without	Y=8.254188+0.008356x+0.053963x^2-0.153017x^3-0.027192x^4; application std. Error:0.113454
With	Y=6.09258+0.01665x+0.06180x^2-0.09878x^3-0.09878x^4; application std. Error: 0.08557
	Night
Without	Y=7.1267+0.1064x-0.2848x^2-0.1425x^3+0.1809x^4; application std. Error: 0.3472
With	Y=5.39629+0.02223x-0.35140x^2-0.05613x^3-0.01824x^4; application std. Error: 0.26348

Table 4. Polynomial Regression Polynomials Entrance - Dentistry

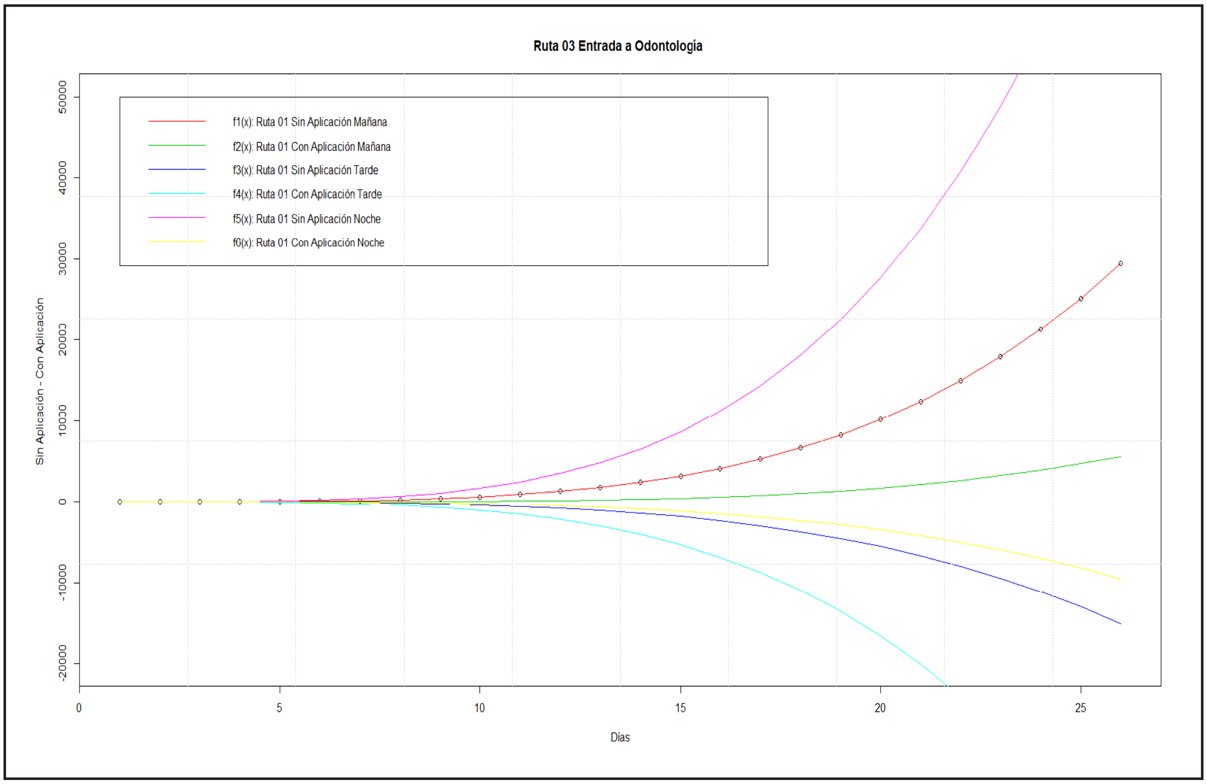

Figure 7. Route 03

	Morning	**Afternoon**	**Night**
Without application	Residualstandard error: 0.3622 on 21 degrees of freedom. Multiple R-squared: 0.09427. Adjusted R-squared: - .07825. F-statistic: 0.5464 on 4 and 21 DF. p-value: 0.7036	Residualstandard error: 0.2481 on 21 degrees of freedom. Multiple R-squared: 0.03863. Adjusted R-squared: -0.1445. F-statistic: 0.211 on 4 and 21 DF. p-value: 0.9294	Residual standard error: 0.4746 on 21 degrees of freedom. Multiple R-squared: 0.07315. Adjusted R-squared: - 0.1034. F-statistic: 0.4144 on 4 and 21 DF. p-value: 0.7963
With application	Residualstandard error: 0.2585 on 21 degrees of freedom. Multiple R-squared: 0.06193. Adjusted R-squared: -0.1168. F-statistic: 0.3466 on 4 and 21 DF. p-value: 0.8434	Residualstandard error: 0.172 on 21 degrees of freedom. Multiple R-squared: 0.0741. Adjusted R-squared: -0.1023. F-statistic: 0.4202 on 4 and 21 DF. p-value: 0.7923	Residual standard error: 0.421 on 21 degrees of freedom. Multiple R-squared: 0.06538. Adjusted R-squared: -0.1126. F-statistic:0.3673 on 4 and 2 1 DF. p-value: 0.8292
Residual standard error	Without application – With application: 0.3622>0.2585 10.37%	Without application – With application: 0.2481>0.172 7.61%	Without application – With application: 0.4746>0.421 5.36%

Table 5. Doctor’s offices 900 - X-rays

	Morning
Whithout application	Y=8.28197-0.28998x+0.33269x^2-0.12023x^3-0.27842x^4; std. Error: 0.36220
With application	Y=6.04818-0.09451x+0.24306x^2+0.03213x^3-0.15354x^4; std. Error: 0.25847
	Afternoon
Without application	Y=10.39102-0.20527x+0.04714x^2+0.02009x^3-0.08481x^4; std. Error: 0.24813
With application	Y=7.37193-0.08826x+0.10551x^2+0.09809x^3-0.14560x^4; std. Error: 0.17204
	Night
Without application	Y=8.02909-0.19246x+0.16977x^2+0.54261x^3+0.11300x^4; std. Error: 0.47457
With application	Y=6.37685-0.31408x+0.14169x^2+0.37461x^3+0.03661x^4; std. Error: 0.42101

Table 6. Polynomial Regression Polynomials Doctor’s offices 900 - X-rays

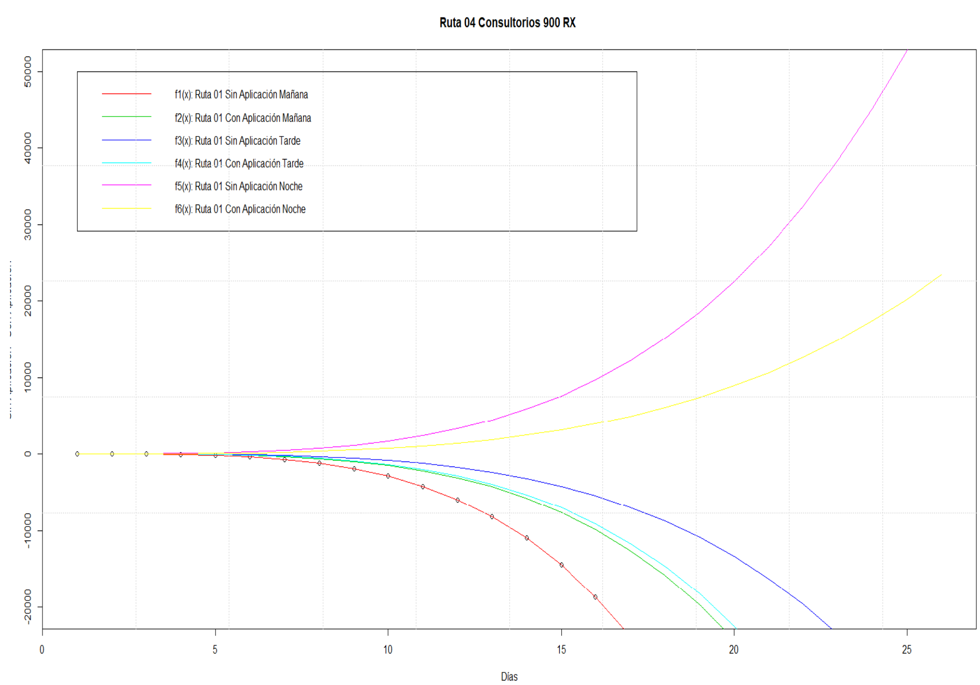

Figure 8. Route 04

In general, it can be stated that in all the routes generated as a function of time and that were taken from with the application, they are better than the routes that have been carried out without the application, in addition to the use of the polynomial regression model adjusted to fourth power its prediction level is better than that of the linear regression line.

The absenteeism rate during the execution month of the proposed model was 9%, while in previous months in which there was no tool to automate the processes of internal mobility and information deployment, there was an absenteeism index 12% denoting a noticeable improvement of 3% of assistance, approximately 15,000 patients per month.

4. Conclusions

By not adapting to the digital age, health centres do not have the necessary resources or are not properly optimized to innovate internal processes in order to improve the quality of medical services, which makes it more complicated to adopt new technological trends such as e-Health.

Thanks to the present study, it was possible to study and analyze the different factors that affect absenteeism to medical appointments, in order to provide a technological solution that helps the delivery of information to patients and the improvement of internal mobility, for that reason the concepts and characteristics of e-Health were used that allowed to have a base guide of good practices in the automation of the studied processes.

The proposed A * algorithm proved to be adequate by providing the mostoptimal routes in most cases, however, it presents certain problems when applied on routes with many obstacles involved generating incongruities in the final routes.

The study allowed us to validate that there is a reduction in the absenteeism rate at the “Centro de Salud Integral Asistanet”, during the time it was tested, thus demonstrating that e-Health should be progressively implemented in the health centres of the country to support the different existing processes in the health area.

5. Recommendations

For the deployment of the prototype, it is essential to have a means in which the patient can access the application in case of not having a mobile device or scanning the QR code, to improve the user experience and offer greater autonomy.

In places with little GPS satellite coverage, it is recommended to use devices that allow improving the accuracy in the location since the range of this tends to increase generating inaccuracy in the calculation of the routes.

For the gathering of results, it is recommended to consider a longer period of time in order to determine more accurately the absenteeism index generated in the health centre.

For future work it is recommended to complement the prototype by following the assigning and managing shifts process, allowing to obtain the data of the patient’s medical appointment, and thus directly access the route without the need for the latter to perform the search in the application. Significantly improving internal mobility times.

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