Prototype System of Geolocation Educational Public Transport Through Google Maps API

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Abstract. Urban traffic complications in most underdeveloped countries and congestion in all metropolitan areas has become a daily problem with a difficult solution. Disorganized mobility of drivers and pedestrians along with the increase in travel time, non-compliance with schedules, air pollution and intolerable sound levels, have harmful effects on human health. Therefore, this research describes a geolocation system of urban transport through a mobile application developed on the Xamarin platform. Drivers send the latitude and longitude points when starting a route, this data will be sent to the SQL SERVER online database server, using the SmarterASP.NET platform. By developing the geolocation system in ASP.NET, the coordinates are available to users in an interval of 5 s. The developed interface shows a location map, where the route in real time is presented. It also shows the administration of users, drivers, buses, assignment of routes, assignment of buses and registration of static routes. Being a prototype system, the university transport system has been taken as an object of study to corroborate its correct operation with the respective experimental tests. Satisfaction surveys have also been carried out on a group of 300 people, among students and university teachers and their validation is carried out through the Technological Acceptance Model (TAM). To interpret the results, Kendall Tau-b correlation analysis was used, obtaining positive correlation values with a high significance value.

Keywords: Public transport · Cloud computing · Databases · Global positioning system · Smart cities

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1 Introduction

Throughout history, the imbalance between developed and developing countries has been latent, as well as corruption and lack of government measures [1–3]. In addition, it must be added the excessive population increase in the poorest regions and the gradual aging that represents a deficient technological growth [4]. All this stuff has caused the increase in inequality in Latin America, the quality of life reduction and a deficient economic and social development, with serious consequences in cultural and environmental aspects [5]. Population growth expectations predict an accelerated increase in the urban population, so by 2020 it is expected to exceed 500 million[1]. That is why world governments seek to have a prospective vision of the situation and carry out future planning on sustainable models of citizen mobility [6–8].

People daily movement and the development of their activities are facilitated by using public transport [7, 9, 10]. Therefore, it is expected that such transport is ready for use when necessary and is in good condition on the journey from the point of origin to the destination. Given human needs, several types of land, sea and air transport have been developed which have evolved according to the social and economic conditions of the environment [9]. Within the metropolis, most common transport is the bus, a vehicle that makes a preset route through defined stops and can transport a large number of passengers [11]. Thanks to new technologies and advances in computing, transport administration is easier by using management programs, office applications or geolocation applications, as well as online geolocation which is a term that has gained great importance since the appearance of the Internet and has become a service that can be offered for various applications [12–14]. The Global Positioning System (GPS) was developed last century for military uses, although it was later used for civil use, which combined with the use of internet represents an important current tool [15].

2 Related Works

Problems in the efficient administration of urban transport have affected several cities of the terrestrial globe. It has led to the development of several studies in this regard. Creating efficient public transport systems that attract users is a challenging task in contexts where public transport control is divided between several actors. [16] presents a systematic review of several works with a focus on the development of understanding, on how to improve conditions for public transport. These articles allow us to understand the critical challenges in planning and implementation of measures to increase travel in public transport, how to face the latent problematic and, advantages and disadvantages of different labor practices.

The study of [15] presents the city reality of Dhaka, one of the largest and most overpopulated in the world, where most people depend on public transport for internal mobilization. Bus is the main public transport but the gap between supply and demand is large, since the number of buses is low compared to the number of passengers.

[1] https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.

In addition, there is no respect for preference seats such as those for pregnant women, older adults and people with disabilities, since passengers compete to get into the units. That is why the initiative of the Indian government is described, to generate a culture of respect and friendly attitude between passengers and bus staff, as well as the attachment to morality to solve their inconveniences when using the public transport. Another factor to consider is the definition of schedules in public transport, so in [16] a heuristic approach is shown to improve this condition and maximize passenger service while respecting an operating cost budget. The results of this case study in The Netherlands indicate that including line planning modifications allows to obtain schedules with a higher passenger service compared to the use of schedule modifications.

The management of public transport through technological platforms has been applied in several environments, as can be seen in [17]. Here we briefly describe the implementation of a new cooperative system for the location of buses with BLE devices (Bluetooth low energy). BLE devices are on a bus and have a GPS receiver, the developed applications are compatible with the participants' smartphones and a cloud service is established. This interactive bus location system is a demo version and therefore does not present relevant results. For its part in [18], a bus location system is developed, to eliminate user concerns about the arrival time of the units at the various stops in the city of Nonoichi. In this study it has been proposed to use Wi-SUN and LoRa; the first with a short transmission distance and requires many repeaters, while the second reduces the number of repeaters by 75%. Connectivity tests are carried out to support this proposal, demonstrating that LoRa offers better benefits at a lower economic cost.

Considering the importance and applicability of the use of online geolocation in transport management, the objective of this paper is to show the evaluation results of the tracking different routes of a bus line belonging to a state university. This allows users to know the location of buses in real time and to better organize their time when performing their school and social activities. Tests carried out allow us to demonstrate the usefulness of this system and, through surveys, know the user satisfaction. To measure the acceptance of this proposal and the impact produced at social level, a quantitative evaluation is performed using TAM. This work is composed of five sections and as an opening is the introduction to the subject in the first section. Section 2 presents related works and Sect. 3 the implementation of the proposal. The analysis of results and conclusions are described in Sects. 4 and 5 respectively.

3 Implementation

Technology development in smartphones (main hardware components of the system) and the good features they offer, allow greater interaction with the final user, better performance and the expansion of this proposal. Once identification, selection and acquisition stage of the main elements is completed, the design of the software architecture used is presented. As shown in Fig. 1, the process begins with online coordinate storage, where routes can be viewed in real time. On the other hand, there is the system administration, which includes: selection of users, drivers, buses, route

assignment, bus assignment and registration of static routes and their design, all of which can be seen in Fig. 2.

Once the driver enters the application through an authentication process, he will start the assigned route. The bus positioning points will be sent to the server every 5 s. This time interval is established in the mobile application and can be parameterized. At the same time, users who use the application with said profile will be able to visualize in real time the route of the transport units that are active at that time, clearly identifying the route of their interest.

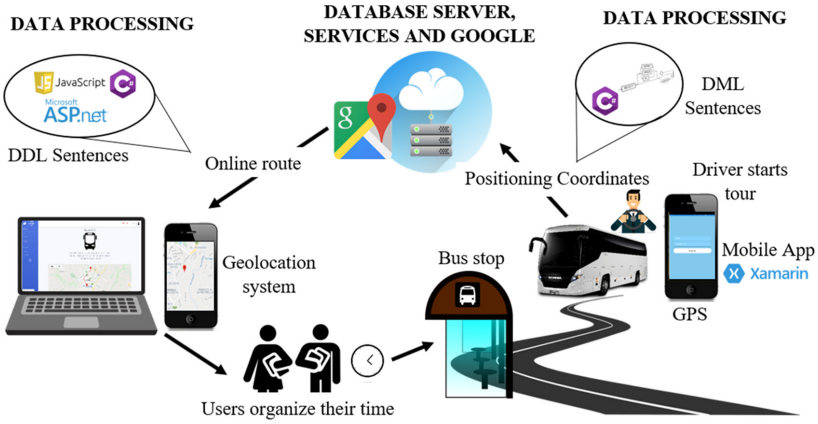


Fig. 1. General system diagram.

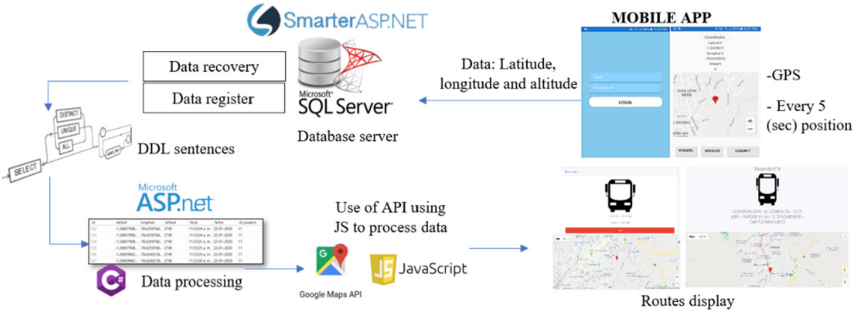


Fig. 2. Architecture used for online coordinate storage and visualization of routes in real time.

3.1 Database Model

The logical structure of the relational model that will be used is described in Fig. 3, including the relationships and limitations that allow determining the way of storing data and how it is accessed. By defining this model, the assignment of different profiles according to the user is enabled, facilitating the management and control of the information and the generation of reports on the routes offered.

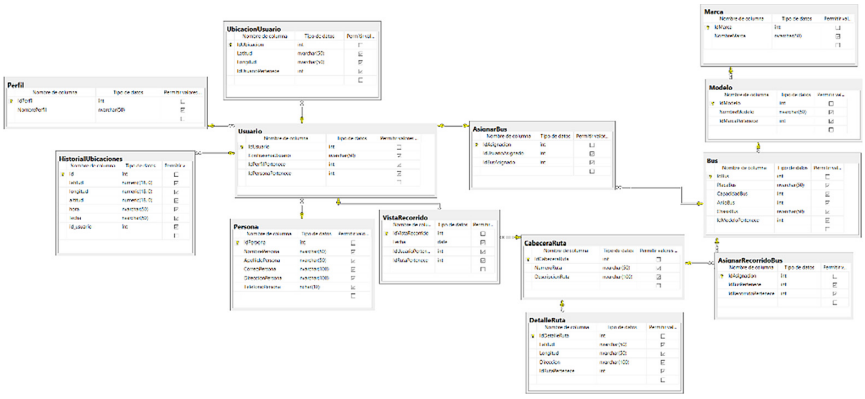


Fig. 3. Relational model of system database.

3.2 Web System Development

The architecture developed for this application is presented in Fig. 4, where the separation of the presentation, business, messaging and data layers is visualized. The purpose of the model developed is to achieve code reuse, ease of standardization, data transport, dependency between layers, decoupled code and ease of application maintenance.

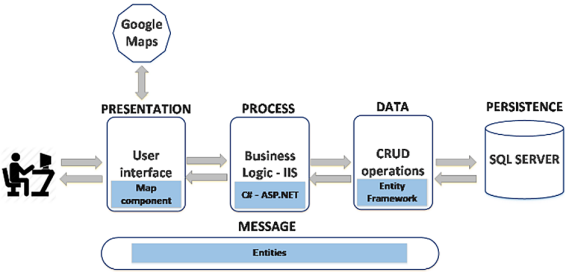


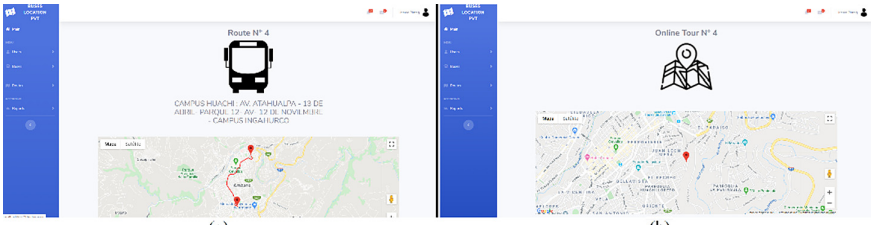
Fig. 4. Layered architecture.

The presentation layer is responsible for interacting with the client or end user, i.e. the interface in which all control and display options are presented. This layer communicates with the business or intermediate layer, responsible for implementing all business rules and dictates the application management guidelines. It also will maintain a dialogue with the data layer, which will handle the data persistence towards the engine and provide the response data towards the presentation layer. In this interface simple and intuitive forms have been developed, which allow the handling of several profiles, transport units, routes and reports, as show in Program code 1.

The main window contains all the established routes so; the user can choose the one of his convenience. In each case, a new window is displayed where the main parameters of this route are detailed, as can be seen in Fig. 5 (a). Routes shown are obtained from database server through DDL sentences, whose manipulation depends on the layer architecture described previously. In order to view the routes online, the user must enter the route of interest, which will be presented if it is active. Figure 5 (b) shows the complete route made by a conductor through an interface designed, as well as the assigned transport unit. One marker is located at the starting point and another at the arrival point. These data define positioning points in both latitude and longitude, thus managing to trace the entire path through the streets in which it is mobilized. Bus location is shown on a map with a marker and within 5 s its position will change as the bus moves. With this information the user can organize better their mobilization time in order to reach the transport at a desired time and fulfill their academic and social activities.

Program code 1. Management of Google Maps API within the Forms through JavaScript.

```
<script type="text/javascript">
  function initialize() {
        var primeraposicion =<%=RecuperarValoresPrimerPosicion() %>;
    // Map settings
    var mapProp = {
       zoom: 15,
       center: primeraposicion,    };
    // Adding the map to the Google Map id tag
    var map = new google.maps.Map(document.getElementById("map_canvas"), mapProp);
    // Route coordinates
        var flightPlanCoordinates = <%=RecuperarValores() %>;
        var ultimaposicion =<%=RecuperarUltimaPosicion() %>;
        var marker = new google.maps.Marker({
           position: ultimaposicion,
              map: map      });
        var marker1 = new google.maps.Marker({
           position: primeraposicion,
              map: map     });
    // Route settings (coordinates, line color, etc.)
    var flightPath = new google.maps.Polyline({
      path: flightPlanCoordinates,
      geodesic: true,
      strokeColor: '#FF0000',
      strokeOpacity: 1.0,
      strokeWeight: 2,
      travelMode: google.maps.TravelMode.DRIVING});
    // Creating the route on the map
    flightPath.setMap(map);    }
    // Initializing the map when the page loads
    google.maps.event.addDomListener(window, 'load', initialize);
  </script>
```



(a) (b)

Fig. 5. (a) Form for viewing an established route. (b) Form for viewing a route in real time.

Google Maps API was used within the forms where the management of maps is indicated, data recovered from business layer is used through the JavaScript by following the process:

- Obtain a key from the Google Maps API in: https://cloud.google.com/maps-platform/maps/?hl=es
- Load the JavaScript library from the Google Maps API.
- Management of the methods offered by the API through JavaScript.

The API provides functions that help to manipulate the data obtained from database server and after a conversion of the information, it can be displayed on a map or in a table. Within the forms where the sending or retrieval of data is planned, methods that interact with the presentation layer were performed, as shown in Program code 2.

Program code 2. Method for registering a new user, sending and retrieving data from the Business layer.

```
private void registrarNuevoUsuario()
  {  // Register Person
     Persona personaNueva = new Persona();
     personaNueva.NombrePersona = TextBoxNombre.Text;
     personaNueva.ApellidoPersona = TextBoxApellido.Text;
     personaNueva.CorreoPersona = TextBoxCorreo.Text;
     personaNueva.TelefonoPersona = TextBoxTelefono.Text;
     personaNueva.DireccionPersona = TextBoxDireccion.Text;
     personaNueva = PersonaNegocio.GuardarPersonaNegocio(personaNueva);
     persona = personaNueva;
     // Register User
     Perfil perfil = new Perfil();
     perfil = PerfilNegocio. devolverPersonaxNombre (DropDownListPer-
fil.SelectedItem.ToString());
     nuevo.IdPerfilPertenece = perfil.IdPerfil;
     nuevo.ContraseniaUsuario = TextBoxContrasenia.Text;
     nuevo.IdUsuarioPertenece = persona.IdPersona;
     nuevo = UsuarioNegocio.GuardarUsuarioNegocio(nuevo);
     ClientScript.RegisterStartupScript(GetType(), "mostrarmensaje", "usuarioRegistrado();",
     true);
  }
```

The business layer is responsible for the logical processing of the application. In this layer the user's requirements are received and the responses are sent after the process while all the rules that must be followed are established. Therefore, methods were developed that communicate with both the presentation layer and data layer. Such methods are called from the presentation layer to transport data from forms, so this layer is the responsible to do the call to methods belonging to the data layer with which it wants to communicate.

The data layer is responsible for accessing, storing and retrieving all system information. It is here that connections to the database server are implemented, stored procedures are invoked and information persistence is managed from the business layer. Therefore, methods were developed that contribute to the connection of DML or DLL with the server located on the SmartASPNET platform, as shown in Program code 3.

The entity layer allows the transport of custom classes through all layers that are part of the architecture. This layer benefits data mobility, maintaining the same communication criteria in the project, regardless of the system's data access technology.

Program code 3. Method in data layer for user profile storage.

```
public static Persona GuardarPersonaDatos(Persona personaNueva)
{ try {
   SqlConnection connection = new SqlConnection(Settings1.Default.Conexion);
   connection.Open();
   SqlCommand cmd = new SqlCommand();
   cmd.Connection = connection;
   cmd.CommandType = System.Data.CommandType.Text;
   // DML statement to register a person on the database server
   cmd.CommandText = @"INSERT INTO [dbo].[Persona]
   ([NombrePersona]
  ,[ApellidoPersona]
  ,[CorreoPersona]
  ,[DireccionPersona]
  ,[TelefonoPersona])
    VALUES
(@NombrePersona,@ApellidoPersona,@CorreoPersona,@DireccionPersona,@TelefonoPer
sona);SELECT SCOPE_IDENTITY()";
   cmd.Parameters.AddWithValue("@NombrePersona", personaNueva.NombrePersona);
   cmd.Parameters.AddWithValue("@ApellidoPersona", personaNueva.ApellidoPersona);
   cmd.Parameters.AddWithValue("@CorreoPersona", personaNueva.CorreoPersona);
   cmd.Parameters.AddWithValue("@DireccionPersona", personaNueva.DireccionPersona);
   cmd.Parameters.AddWithValue("@TelefonoPersona", personaNueva.TelefonoPersona);
    var idpersona = Convert.ToInt32(cmd.ExecuteScalar());
    personaNueva.IdPersona = idpersona;
    return personaNueva; }
  catch (SqlException ex)  {  var error = ex.Message;    }
return personaNueva;  }
```

3.3 Mobile Application Development

Due to the advantages that current smart devices have and the ease of using the built-in GPS, a mobile application is developed using Xamarin[2] [19]. This mobile application was developed based on the model presented in Fig. 6, using ASP.NET with the programming language C #. Bootstrap was used to design the interface, allowing to work with CSS and JavaScript together.

The main screen can be seen in Fig. 7 (a), where the user can choose between creating a new account or registering with an existing account. If a new record is selected, it is directed to a form for entering information and selecting a profile. (Figure 7 (b)). If the user has a registered account, it will be validated through an authentication process by sending a security code to the user's email, and once registered, the application will be deployed based on the profiles associated with this account (administrator, driver or user). The option for password recovery is also presented, when user does not remember it.



Fig. 6. Model of the mobile application.

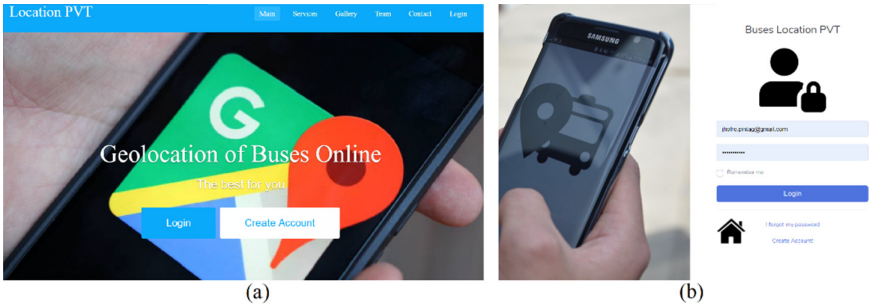


Fig. 7. Application screens: (a) Main window. (b) Registration form.

To save the positioning online, the driver will use the mobile application, with a procedure similar to the one followed in the web application, i.e. profile validation will be done with a previously registered email and password. The Program code 4 allows the acquisition of bus positioning data (latitude and longitude), time and date belonging

[2] https://dotnet.microsoft.com/apps/xamarin.

to a specific driver, to be sent to the storage method. Through this data the user can view the route online through the web system and the mobile application. Based on the Program code 5 you can obtain the real-time tour, as well as the positioning coordinates. All this data will be stored in the database that is hosted on the SmartASPNET server. To achieve this process the Xam.Plugin.Geolocator library was used, which is available in the package manager: NuGet.

Program code 4. Management of Google Maps API within the Forms through JavaScript.

```
public static HistorialUbicacionEntidad GuardarHistorialUbica-
cion(HistorialUbicacionEntidad historialUbicacion)
    { try {
        SqlConnection connection = new SqlConnection(url);
        connection.Open();
        SqlCommand cmd = new SqlCommand();
        cmd.Connection = connection;
// DML statement to register the coordinates on the database server
        cmd.CommandText = @"INSERT INTO [dbo].[HistorialUbicaciones]
                                ([latitud]
                                ,[longitud]
                                ,[altitud]
                                ,[hora]
                                ,[fecha]
                                ,[id_usuario])
                            VALUES
                                (@latitud
                                ,@longitud
                                ,@altitud
                                ,@hora
                                ,@fecha
                                ,@id_usuario);SELECT SCOPE_IDENTITY()";
        cmd.Parameters.AddWithValue("@latitud", historialUbicacion.Latitud);
        cmd.Parameters.AddWithValue("@longitud", historialUbicacion.Longitud);
        cmd.Parameters.AddWithValue("@altitud", historialUbicacion.Altitud);
        cmd.Parameters.AddWithValue("@hora", historialUbicacion.Hora);
        cmd.Parameters.AddWithValue("@fecha", historialUbicacion.Fecha);
        cmd.Parameters.AddWithValue("@id_usuario", historialUbicacion.IdUsuario);
        cmd.CommandType = System.Data.CommandType.Text;
        var id = Convert.ToInt32(cmd.ExecuteScalar());
        historialUbicacion.Id = id;
        connection.Close();
        return historialUbicacion;
      } catch (SqlException ex)
      { Console.Write("" + ex);
        return null;     } }
```

Program code 5. Method for obtaining real-time coordinates in an interval of 5 seconds

```
private async void IniciarLocalizacion()
  {   // Instantiate position variable
     var locator = CrossGeolocator.Current;
      locator.DesiredAccuracy = 100;
      if (locator.IsGeolocationAvailable)
       {  if (locator.IsGeolocationEnabled)
            {  if (!locator.IsListening)
              {  // Set time to obtain coordinates
                 await locator.StartListeningAsync(new TimeSpan(0, 0, 5), 0.30);   }
               locator.PositionChanged += (cambio, arg) =>
       {  // Get the coordinates
             var loc = arg.Position;
              lat.Text = loc.Latitude.ToString();
              lon.Text = loc.Longitude.ToString();
              altura.Text = loc.Altitude.ToString();
               // Instantiate the method of saving position in the database
               CambiarDePosicionMapa(loc.Latitude, loc.Longitude);
               GuardarHistorialUbicacion(loc);   }; }
        else{
            await DisplayAlert("Aviso", "Por favor active el  GPS", "Ok");   }  }  }
```

4 Result Analysis

Once the implementation is finished, this prototype system is used by users belonging to a university campus. When a user enters the web platform or mobile application to visualize a specific route, the server counts this information by the use of an accumulator and presents it in a tabulated way as can be seen in Fig. 8. In the same way, the analysis of the concurrence points between routes made by drivers was carried out, thus determining the busiest road traveled. This result was performed through the use of heat maps, which is offered by the Google Maps API as shown in Fig. 9.

ROUTE	N° VIEWS
Route 1	330
Route 2	270
Route 3	400
Route 4	460
Route 5	205
Route 6	278
Route 7	175
Route 8	198
Route 9	365
Route 10	434
Route 11	239

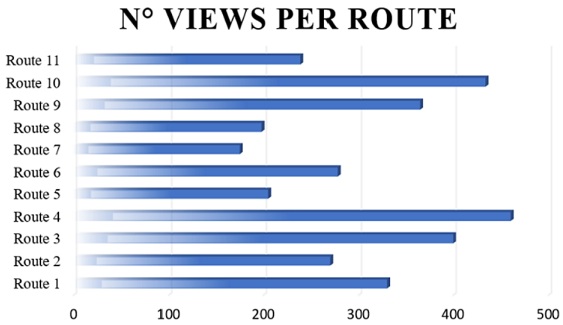


Fig. 8. Statistical data obtained from the route most viewed by users.

In Fig. 10, it is shown a screen developed with the purpose of displaying reports based on an analysis of the crowdest points by drivers when making the established routes, this data allows a better administration of the geolocation system. With these reports the usability of the system and the exact number of users who have used the platform can be determined, differentiating their profile: driver, administrator or normal user.

The quantitative acceptance assessment (surveys) has been applied to 300 users and has allowed us to obtain relevant information about this experiment. 51% of the participants are female, 95% are students and 86% do not have their own or family vehicle for mobilization. 76% live in urban sectors and the remaining 24% in rural areas and other surrounding towns; 89% live in areas greater than 10 km away from the establishment of higher education. From an ethnic perspective, 79% of the surveyed group is considered of mixed race.

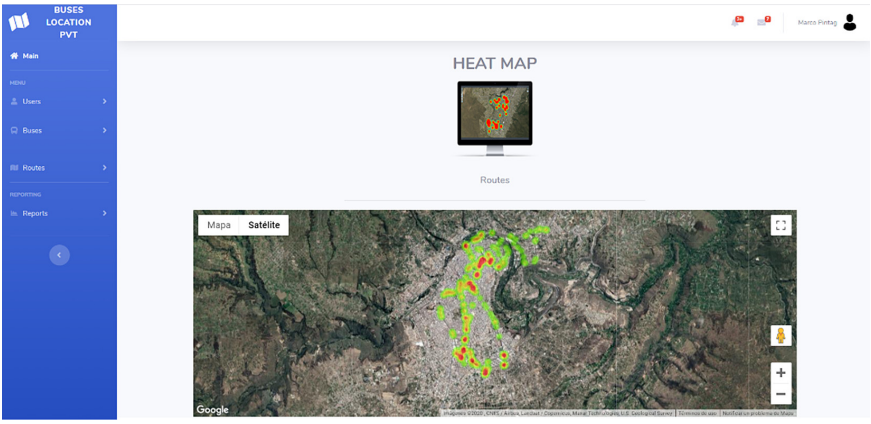


Fig. 9. Heat map obtained from the routes performed.

To measure the acceptance of the application, it was proposed to carry out a quantitative evaluation. In this sense, the Technological Acceptance Model (TAM) was developed by Davis and has become one of the most popular models for predicting the use and acceptance of technology and information systems [20]. According to Davis, the fundamental objective of TAM is to identify the factors that determine the use of Information and Communication Technologies (ICT) from the user's perspective. TAM suggests that perceived utility and perceived ease of use are determining factors in an individual's intention when using a system. The relevance and impact of the TAM results, in the aforementioned studies, support the relevance and effectiveness of this methodology [21–23].

Based on the criteria of the TAM model [24], it can be defined the level of acceptance that this proposal has by users, its description is made below.

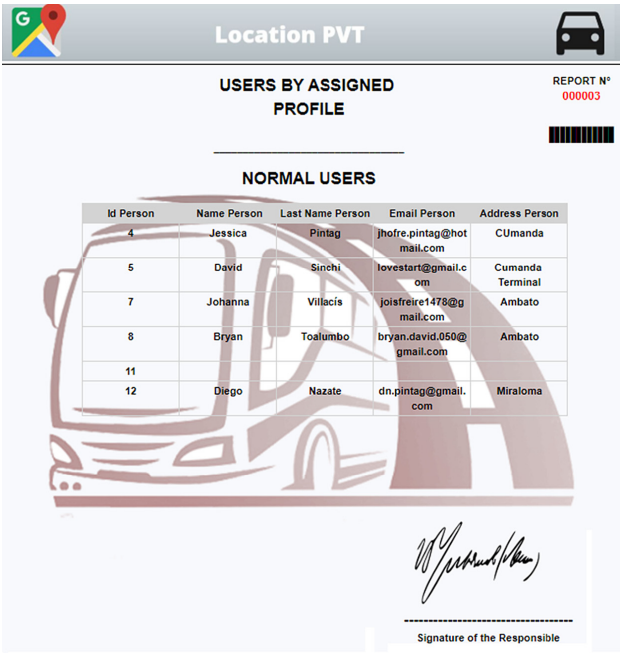


Fig. 10. Report of users issued by the Geolocation System

- The perceived ease of use when using the tool positively affects the attitude of use of the application.
- The application ease of use promotes its implementation as part of the information management of an efficient transport service.
- The feedback of the application information is strongly correlated with the optimization of the users' time with respect to the transport service routes. The user-friendly of the map allows intuitive access to georeferenced information.
- The interactive map is a fundamental component of the proposal and promotes the future use of the tool in the analyzed segment.

The values of the criteria in correspondence with their means and standard deviations are shown in Table 1. Considering a Likert scale with values from 1 to 5, its approval has been corroborated.

Using a Kolmogorov-Smirnov normality test it was shown that results of the technological acceptance criteria do not follow a normal distribution, with a p-value of 0.00. Therefore, the data analysis was based on a non-parametric correlation using Kendall's Tau-b. The resulting correlation between the elements was significantly positive as recorded in Table 2.

Table 1. Mean and standard deviation of TAM model criteria

TAM model criteria	Mean	Standard deviation
Attitude towards use	4.62	0.32
Perceived ease of use	4.38	0.61
Perceived profit	4.45	0.58
Intention to use	4.36	0.57

Table 2. Kendall's Tau-b table

N = 300		P1	P2	P3	P4
1. Do you think that when using the app for recovery information about transport units would you be satisfied?	CC	**,527****	,203**	,190**	,244**
	AS	0,000	0,000	0,000	0,000
2. When analyzing the software prototype proposed, do you consider that in a short time you can become an expert user in this app?	CC	0,070	,227**	,124*	,173**
	AS	0,200	0,000	0,023	0,002
3. When analyzing the software prototype proposed, do you think that its design facilitates its use?	CC	,233**	0,084	,386**	,276**
	AS	0,000	0,104	0,000	0,000
4. Is the access to information through the map easy for you?	CC	,212**	0,087	,278**	,307**
	AS	0,000	0,094	0,000	0,000
5. Does the map component highlight the value of the information that is managed in the application?	CC	,244**	,205**	,314**	1,000
	AS	0,000	0,000	0,000	
6. Do the generated reports highlight the value of the information that is managed in the application?	CC	,239**	0,075	**,408****	,130*
	AS	0,000	0,140	0,000	0,014
7. Is the usefulness of the map significantly high?	CC	,203**	,155**	,316**	,397**
	AS	0,000	0,003	0,000	0,000
8. Would you suggest the use of the application for the management of transport service information?	CC	,154**	**,426****	,302**	,378**
	AS	0,004	0,000	0,000	0,000
9. Would you use the application for better time management with respect to the transport service?	CC	,204**	0,076	**,609****	,299**
	AS	0,000	0,142	0,000	0,000

Abbreviations: P1: Software prototype considers this to be easy to use. P2: Prototype does not require much effort to use. P3: Access to information in an easy way. P4: The map component helps to understand the information. CC: Correlation coefficient. AS: Asymptotic Significance (Bilateral)

5 Conclusions

The prototype system that has been developed has a high functionality since it allows users to reduce waiting periods with uncertainty, organize their time more efficiently, access to information reports and interactive map presentation. Based on the results obtained, it has been possible to show that there are routes with greater concurrence than others, which demonstrates the need to take actions, such as planning to incorporate other transport units on these routes due to the large number of passengers. By using heat maps, points with the highest traffic can be established and thus suggest a possible change of streets when making the route, reducing the time taken to complete the entire route and improving the traffic congestion of the city.

The study shows quantitatively that university users (teachers and students) agree with the use of this type of applications. In this way, transport service routes and reporting to the authorities are better managed. TAM evaluation results allowed to confirm that the ease of use, the intention of use and the utility are highly correlated with the tool handling. Although this application has been tested with a state university, it is a pilot, for its good performance it has been included as part of the metropolitan management system, which will allow obtaining new results as a future job and being the basis of future research in Latin America.

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