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# Development of a collaborative mapping web application to identify risk areas applied to the municipality of Nova Friburgo/RJ

## *Desenvolvimento de uma aplicação web de mapeamento colaborativo para identificação de áreas de risco aplicada ao município de Nova Friburgo/RJ*

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**Abstract:** With the increasing use of collaborative mapping applications seeking to achieve different objectives, mapping with humanitarian initiatives has been highlighted, mainly caused by devastation by natural causes. These initiatives mainly seek to meet mapping needs that can assist in the recovery of the affected region. The mapping of factors seeking to prevent disasters is still associated with public administration, however, due to the lack of resources for traditional mapping, many Brazilian municipalities do not have mapped areas of risk that can cause disasters. Thus, initiatives to identify factors that can assist in disaster prevention using collaborative mapping show up as a great potential for application in public administration. This study aimed to develop a web application for collaborative mapping of points of flooding and landslides in the municipality of Nova Friburgo, State of Rio de Janeiro, Brazil. With this application, it is intended that the residents of the locality can carry out the identification and control of places with potential risks, to identify unstable places together with the public administration, allowing them to carry out actions that seek to solve the problems pointed out by the platform's collaborators.

**Keywords:** Collaborative Mapping; Web; Risk areas.

**Resumo:** Com a crescente utilização de aplicações de mapeamento colaborativo buscando alcançar diferentes objetivos, tem-se destacado o mapeamento com iniciativas humanitárias, ocasionado principalmente por devastações com causas naturais. Estas iniciativas buscam principalmente atender as necessidades de mapeamento que possam auxiliar na recuperação da região afetada. O mapeamento de fatores buscando a prevenção de desastres ainda são associados à administração pública, entretanto devido à falta de recursos para o mapeamento tradicional, muitos municípios brasileiros não possuem mapeadas áreas de riscos que possam ocasionar desastres. Assim, iniciativas de identificação de fatores que possam auxiliar na prevenção de desastres utilizando mapeamento colaborativo mostra-se como um grande potencial de aplicação na administração pública. Neste estudo visou-se desenvolver uma aplicação web de mapeamento colaborativo de pontos de alagamentos e deslizamentos no município de Nova Friburgo, Estado do Rio de Janeiro, Brasil. Com esta aplicação deseja-se que os próprios moradores da localidade possam realizar um trabalho de identificação e controle de locais com potenciais riscos, tendo como finalidade a identificação de locais instáveis juntamente com a administração pública, permitindo-a realizar ações que busquem a resolução dos problemas apontados pelos colaboradores da plataforma.

**Palavras-chave:** Mapeamento colaborativo; Web; Áreas de risco.

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## 1. Introduction

A Geographic Information System (GIS) presents itself as an important tool for spatial data management, relative to different study areas. It is widespread within the academic and business community, mainly due to the computational advances of the last decades. Transport and logistics, environmental disasters, environmental management, and urban planning are some of the activities, among others, that are helped by map design through the use of a GIS. However, spatial data acquisition usually is an onerous activity, which difficult updating these maps.

With the popularization of Web 2.0, the design of collaborative maps is increasing, especially for allowing the creation of data by part of the platform's users, even those who do not have technical knowledge. (BRAVO; SLUTER, 2018). According to Haklay (2013), collaborative mapping can be seen as an environment to produce geographical information related to different themes (social and/or environmental) and as a tool to update national and international databases using personal computers, GNSS receivers, and cellphones. VGI (Voluntary Geographic Information) is referred to as a special type of "*user-generated content*", according to Goodchild (2007), where the user's voluntary action does not have any stimuli other than its motivation to collaborate. When observing such concepts, it is emphasized that the collaborative mapping platforms also cover VGI platforms (BRAVO; SLUTER, 2018).

An important example of collaborative mapping is the Wikimapia project (<http://wikimapia.org>), which aims to create a geographic database fed by voluntary users and freely available to anyone that has internet access. Within the same context, it is also possible to mention the OpenStreetMap (OSM) project, developed and enhanced with an international effort to construct more elaborate representations of the Earth's Surface. With this application, the aim is to create a free and voluntarily supplied geographic database, mainly seeking to fill a gap in the availability of global geographic information in digital media. According to Albuquerque, Herfort, and Eckle (2016), the OSM project presents great potential in the natural disaster scenario, especially after the results of the collaboration campaigns posterior to the Haiti earthquake in 2010.

The Humanitarian OpenStreetMap Team (HOT) initiative is a team dedicated to humanitarian action and community development through collaborative mapping on a global scale. Its main goal is to supply geographic data that allow the management of natural disasters, the reduction of risks, and the contribution to determining sustainable development. In the context of natural disasters, Albuquerque, Herfort, and Eckle (2016) mention that collaborative mapping is essential to its management, once it collects information and structures it into base maps to support relief efforts, especially in developing countries.

Brazil is exposed to a variety of natural events (such as droughts, floods, and landslides), which most of the cities are not prepared to face, and the risks are multiplied due to the disordered growth and occupation of risk areas. For example, it is possible to mention the occurrence of heavy rains in the mountain region of Rio de Janeiro in 2011 (setting the starting point of management policies and environmental risk in the country (BANCO MUNDIAL, 2012), leaving around 918 dead and more than 30 thousand people homeless, creating a loss of R$ 4.78 billion, according to the estimative of the World Bank.

In Brazil, the Federal Law n° 12.608/2012 instituted the National Civil Defense and Protection Policy (*Política Nacional de Proteção e Defesa Civil* - PNDPC). The Decree n° 10.692 from 3rd of May, 2021, instituted the National Register of Municipalities with Areas Susceptibles to the Occurrence of High Impact Landslides, Sudden Floods, or Related Geological or Hydrological Processes. Still agreeing with this Decree, the areas susceptible to the occurrence of disasters are areas characterized by the relevance of the elements exposed to human and material damage and economic and social loss. These Laws seek, among other skills, the mandatory mapping of risk areas for Brazilian cities included in the registry.

Nova Friburgo was one of the most affected cities in the 2011 floods, reporting 180 thousand affected, concentrating 60% of the population affected by the disaster (BANCO MUNDIAL, 2012). After 7 years the municipality still presents socioeconomic imprints of the 2011 natural disaster, going through recurrent problems related to landslides and floods, mainly caused by the bad administrative management related to the risk areas.

The VGI use applications for mapping natural disasters were observed by Zook et al. (2010) as a source of quick mapping and with a high volume of information, providing rich material for assistance provision during a crisis. Besides that, in the context of natural disasters caused by floods, these applications were already approached by several authors (HORITA et al., 2015; FAZELI et al., 2015, RESTREPO-ESTRADA et al., 2018). However, according to what Horita et al. (2013) and Oliveira et al. (2018) pointed out, there are still few applications that seek to meet the pre-disaster phase.

Aiming to contribute to this theme, this research presents an approach of collaborative mapping directed to the presented issues observed in the municipality of Nova Friburgo. In this context, this research seeks the construction of a web application that allows the residents of the municipality the mapping the region's risk areas, providing them a space that allows obtaining information and allows them to report real problems and needs in the interest area, as well as providing the public administration a tool as a mapping alternative that allows the resource management seeking the mitigation of the observed issues.

## 2. Methodology

Due to the main objective of the research, the collaborative mapping, it was chosen the development of a study case applied to the municipality of Nova Friburgo/RJ. To construct the platform, firstly, it was needed to identify the demands related to obtaining location information and how to make them available over a map base in a virtual environment.

To determine the application's theme, a theoretical survey was carried out in the municipality of the study, observing that it frequently suffers from landslides and floods caused by the irregular land occupation associated with the site geology and the lack of investments in urban infrastructure from the municipalities' administration. In this context, it is possible to observe that the community lacks tools of easy application for obtaining information on the areas susceptible to floods and landslides, establishing the possibility of mapping such areas and making them available on a platform that presents a simple and intuitive interface to the users who have little or no technical knowledge about cartography, adopting the use of point symbols to represent the possible locations of occurrence entered by users.

### 2.1. View of use cases

Figure 1 presents the Use Case Diagram, representing the actors: "Administrator", "Collaborator", and "Common User". It is possible to observe that the actor "Administrator" can practice any type of request to the system, while the others will carry out restricted activities, according to the class in which each user was inserted.

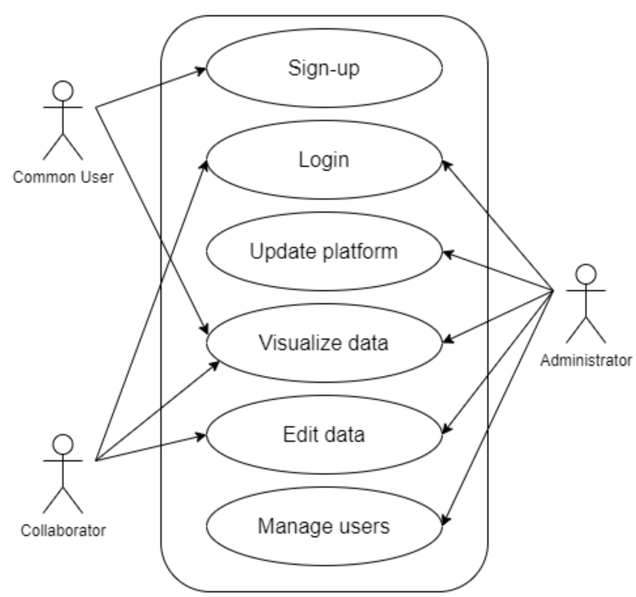


*Figure 1 – Use case Diagram.*
*Source: The author (2022).*

For a better interpretation, Table 1 describes the characterization of each actor.

*Table 1 – Description of the use cases.*

| Actor | Description |
|---|---|
| **Administrator** | Responsible for the platform management (updates, insertion, and elimination of information from the database). |
| **Collaborator** | Main users of the application. The visualization of information inserted by the system administrator and the other users is allowed; can insert information related to the occurrence of landslides and floods, describing them and determining the place of the occurrence. |
| **Common User** | Allowed the visualization of the data on the platform. |

*Source: The author (2022).*

The actors “Administrator” and “Collaborator” have validation action in the application, so that it is possible for them to be registered and realize actions according to their attribution. In the validation of the actor “Administrator”, the system requires the Login and Password to the actor, and the informed data are validated and the access is granted for the actions identified in Figure 1. In the validation of the actor “Collaborator”, the system also requires the Login and Password to this actor, and with the data validated, the access is granted for the actions of the actor “Collaborator”. Table 2 presents a description of each activity related to the actors in the Use case diagram presented in Figure 1.

*Table 2 – Description of the actions predicted in the Use case diagram.*

| Action | Description |
|---|---|
| **Sign-up** | Allows the common user sign-up in the system in the system, thus, being able to become a Collaborator user. |
| **Login** | Realizes the login in the system, to identify the Collaborator or Administrator user, assigning the appropriate activity permissions in the system. |
| **Update platform** | The Administrator user can make changes in the applications, such as insert relevant information for the platform, among other management decisions. |
| **Visualize data** | Access to the map and contribution data made in the application. |
| **Edit data** | Allows editing contribution data made in the application. |
| **Manage users** | Allows defining other users registered as administrators and editing user registrations. |

*Source: The author (2022).*

## 2.2. Development of the application

For the development of the web application, it was used a *framework*. The advantage of using *frameworks* in computational programming is the availability of a collection of tools that speed up the accomplishment of applications predicted by the *framework*. These pre-available tools can be used in the development of applications, decreasing the quantity of coding necessary for creating certain functions that will be available in the application.

Django is a *framework* written in Python, created by Adrian Holovaty in 2005, very popular and especially aimed at web applications with clear and easy coding. Among the advantages of its use is to have several modules developed by several collaborators, that are made available for free so that they can be part of new applications quickly and safely. Version 2.2 of the Django *framework* was used to develop this application. This *framework* provides a standard administrative interface, built according to user-defined Python classes and their respective attributes, that are declared in the database by Django.

Some important concepts for the usage of this *framework* are necessary, such as, for example, the standard structure that most web applications use that help the development of the application, thus minimizing errors in the database coupling, interface, and business logic. This structure is called *Model-View-Controller* (MVC). According to the official Django (DJANGO, 2020) documentation, the MVC pattern is made up as:

a) *Model* (M): responsible for realizing the interface between the database and the application. In this layer are developed the business rules that are applied to the database;
b) *View* (V): It is what can be seen in the web browser from an application;
c) *Controller* (C): It is what can be seen in the web browser from an MVC application. The *Controller* layer is responsible for realizing the connection between the *Model* and the *View*. It uses logic to extract the necessary information from the database and pass them to the *Views*.

Django uses the MVC standard to construct web applications, however, it has its own implementation logic. *Model* are the Python classes are declared in the file "Models.py", which interact directly with de database. The Controller operation is realized by two files, "Views.py", where are declared all the Python functions and the request mapping file named "urls.py". The interaction between the Python functions and the database is presented through templates. Due to this setting, it is possible to consider that Django has an internal model called MTV (*Model-Template-Views*). In Figure 2 is possible to observe the basic MTV structure of how Django works (DJANGO, 2020).

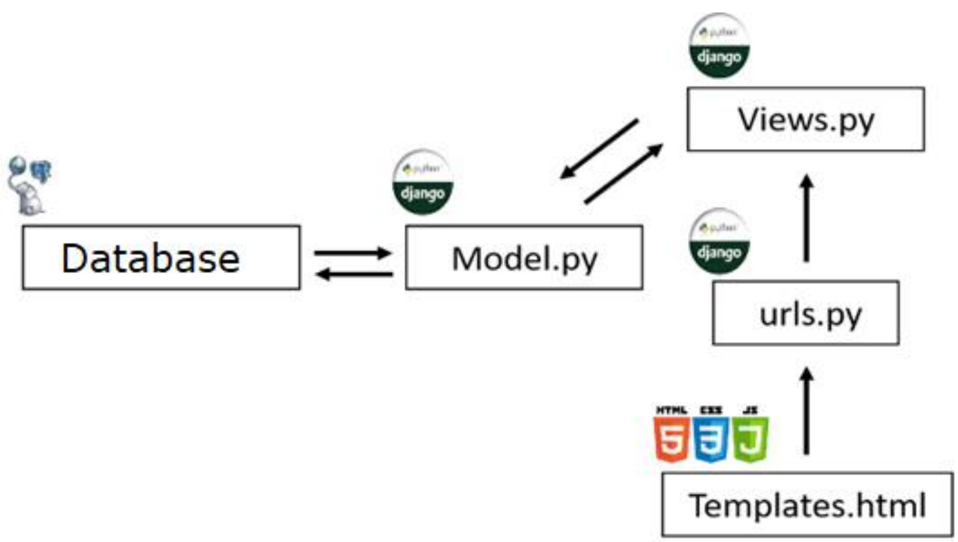


*Figure 2 – Diagram of the functioning of MTV structure.*
*Source: The author (2022).*

The Database Management System (DBMS) chosen to be used in the application was PostgreSQL, together with its extension PostGIS for the geospatial database. This choice seeks to meet the integration of the data with the Django *framework* because it has easy integration with the chosen DBMS, allowing its use both as a database manager for the developed application and to store geospatial data that will be contributed to the application. The PostGIS DBMS and its PostGIS extension are *Open-source* software, with wide adhesion by the community of developers of geospatial applications. This application used version 9.6 of PostgreSQL and version 2.3 of PostGIS.

For the visualization and use of the geospatial database inside the application to be developed, it was used the JavaScript Leaflet library. Leaflet (LEAFLET, 2020) is an O*pen-source* library for interactive maps developed by the Ukrainian Volodymyr Agafonkin in 2011. Leaflet was projected with simplicity, high performance, and usability, having a high quantity of tools to create geospatial applications. This application used Leaflet version 1.6. This library works from a base map, on which the developer or the user of the application can insert new layers of georeferenced files. It supports several formats of files, such as *Web Mapping Service* (WMS) layers, GeoJSON layers, vector layers, and rasters.

The web application to be developed seeks the mapping the occurrence of landslides and floods in the city of Nova Friburgo. The tools used for its development, all in open-source software, were: i) Python *framework* Django; ii) Database Management System PostgreSQL and its spatial extension PostGIS; iii) Leaflet map library.

From the application's interface, the user can add new occurrences and visualize those that were added previously. The web server will be responsible for the communication between the database and the requisitions realized by the users. Once the work is developed in a test platform, the web application was developed on a local server, dismissing the internet access for its compilation. The data was stored in a geographic database, using pgAdminIII. The development of the application was made in a Linux environment, with the operating system Ubuntu 18.04, using the virtualization tool VirtualEnv, used to create an isolated virtual environment for the development of this project.

## 3. Results and discussion

This section aims to present the developed platform for collaborative mapping of risk areas in the municipality of Nova Friburgo, State of Rio de Janeiro, Brazil. For the development of the platform, were created four distinct functionalities: i) user login; ii) user register; iii) form to insert data; iv) query and visualization of data over the digital map. Figure 3 presents the architecture of the system.

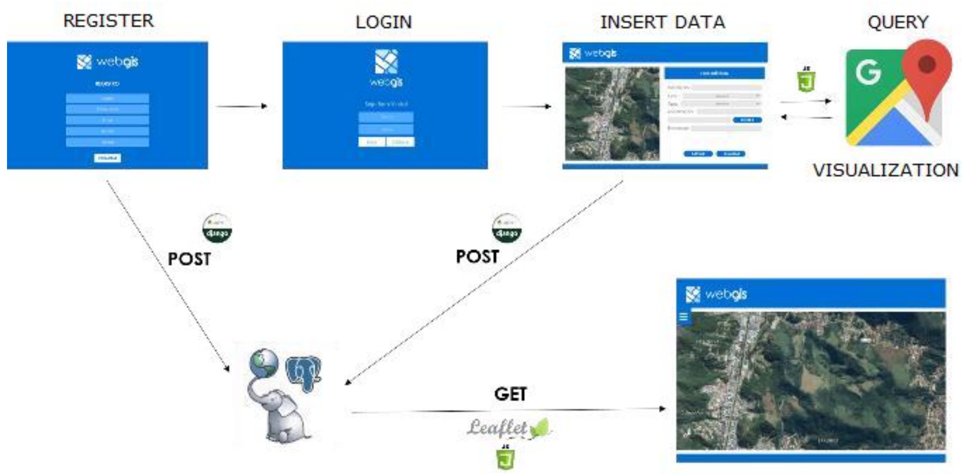


*Figure 3 – Architecture of the proposed application.*
*Source: The author (2022).*

To carry out a collaboration, the user must log in to the system if they already have a registration, otherwise, they must register on the "Registration" page, providing the following information: name, surname, e-mail, username, and password. After this register, the user is able to log in. After the registering on the "Registration" page, the user will automatically be redirected to the "Login" page, in which the username and the password will be filled out, so that the page to insert data to the platform can be accessed.

When accessing a user registered via "Login", the user can carry out the insertion of new occurrences of floods and landslide cases in the perimeter of the municipality studied. From the presented interface, it is possible to observe that the user can add data related to the type of occurrence. Due to the use of JavaScript coding and the Google API, the user can add data by moving the position icon located over the base map or by entering the address in the occurrence form, and automatically the location of the occurrence is performed over the map. Figure 4 presents the page "Insertion Data", for the insertion of collaborative information.


*Figura 4 – Page to insert information.*
*Source: the author (2022).*

When clicking over the "Save" button, the informed data will be added to the database. All the inserted information can be visualized on the main page of the application. To visualize data over the base map, it was used the Leaflet library. In addition to inserting data from user collaboration, other geographic data were inserted on the platform, obtained from the website of the City Council of Nova Friburgo, which can be visualized through the panel responsible for able and disabling the map layers. The icons representing the occurrences were developed aiming to be simple, of easy separation and identification.

Four classes of symbols were created: alert sirens, flood, torrents, and landslide occurrences. Figure 5 presents these symbols. These classes and their respective symbologies were created as a test for the application initially aiming to meet the main needs observed in news related to urban risks and vulnerabilities. However, the Administrator user of the application is able to create new classes and symbologies. Figure 6 presents the main page of the application with fictional contributions as an example, based on the presented classes, used for visualization tests.


*Figure 5 – Pictorical symols for the classes representation: (a) alert sirens (b) floods (c) torrent (d) landslides.*
*Source: The author (2022).*

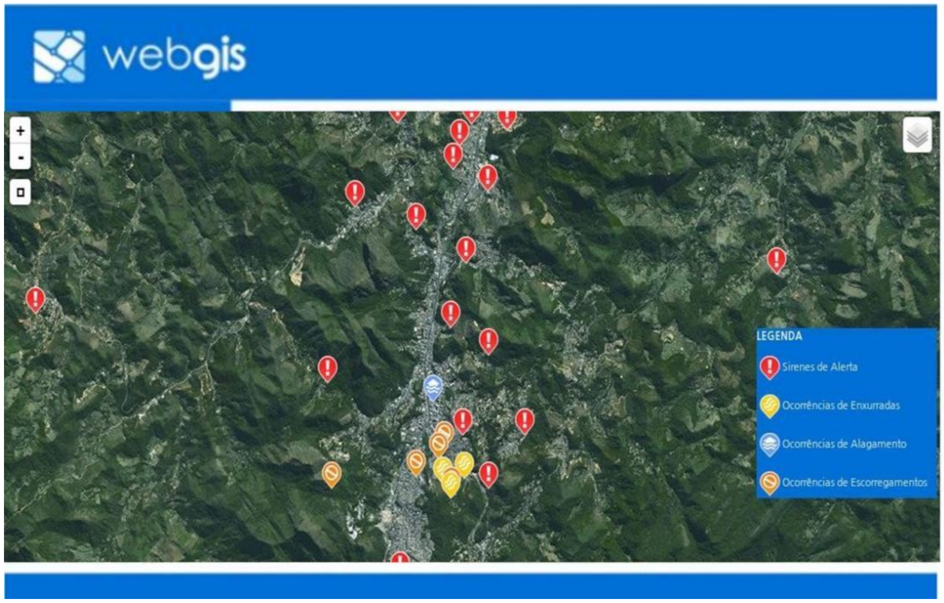


*Figure 6 – Example of data inserted on the platform.*
*Source: The author (2022).*

With the application in the initial phase and the realization of the first prototype of tests, it is possible to realize tests with users, seeking to attend to their needs in relation to the platform's content. The usability of the developed application can also be improved by applying user tests. In VGI collaborative platforms usability is pointed out as a factor that contributes to the user participation in data collaboration (PICANÇO JR., DELAZARI, 2016). Besides that, according to what Lima et al. (2020) point out, the development of geospatial applications with User Centred Design (UCD) practices, that is, with the participation of the user during the development steps of the application, can favor the improvement of the application, turning it more attractive to its target users.

## 4. Final considerations

With the development of the application, it was possible to observe that the elaboration of a collaborative web mapping application presents several challenges, between technical and conceptual. It was sought to use existing tools, such as the libraries and frameworks mentioned, to contour the technical computational complexity. However, even these tools have a certain need for a greater degree of knowledge. The complexity is due, among others presented, to the need to relate different computational languages to accomplish a single application, having as an example the knowledge of the languages used in this work and enough knowledge in the database.

Throughout the work's development, it was possible to mature ideas in the context of collaborative mappings, such as questions related to seeking to translate lay knowledge for technical use. Besides that, many of the steps related to the construction of the platform were modified according to the obstacles found during the work, finding solutions, and, consequently, learning how to solve problems effectively.

In relation to collaborative mapping, it is possible to observe its use potential, mainly as a support to urban management, once the citizens can promote the platform with updated data. In the context of the platform's interface, the challenges observed in relation to its best fit in relation to the user needs can be deepened with usability studies of the created application. This type of analysis did not take part of the scope of this research, but it can be deepened in future works, with analysis of study cases of the created application.

In this specific study case, the municipality of Nova Friburgo suffers every year from flood and landslide points, for which there is no follow-up of these data, related to the locations and quantity of occurrences, available to the population. By mapping these points and verifying their occurrences, the municipality's administration will be able to carry out studies and operations where there is a propensity for flooding and landslides, thus allowing better planning for the resolution of the problems caused by such events. Having this information in hand, the population can monitor and control such solutions.

Marchezini et al. (2017) pointed out the opportunities of VGI use for mapping risk areas, with the participation of the scientific community and integration of society. However, it was possible to observe a gap in the literature regarding the creation of VGI applications seeking to prevent disasters, as pointed out by Oliveira et al. (2018). Thus, with this work, it is hoped that new initiatives can arise in order to meet the demand for these issues in the Brazilian municipalities with potential risk locations. As a continuation of this work, it is desired to analyze other aspects of the platform, such as the study of its usability, analysis of the suitability of the pictorial symbols used, as well as the efficiency obtained from its use by the public administration.

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