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Geographic Information System Exam

Roads registry and road signs Padova Municipality Management

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1 Objective of the Studies

The goal of this project is the development of a Geographic Information System for road maintenance of the Italian city of Padova. The objectives to achieve are the following:

- managing the vertical sign, by providing the possibility of knowing the positions of the signs and their attributes, like type of sign and date of installation and the possibility to add new signs.
- detecting the state of the road network. The system has to store informations about the conditions of the road, i.e. presence of malformations; also it is necessary to collect the maintenance interventions performed.
- complying with the obligation to set up the roads registry according to DM n. 3484 of 01-06-2001 and to comply with national and international standards.

2 Analysis of Requirements

The requirements of the System are divided into three different categories:

2.1 Functional Requirements

2.1.1 Road registry management according to the norm

- **Application for managing the roads**: It is necessary a GIS Web Application that is accessible via all the major browsers; alternatively a desktop GIS application is acceptable. In both cases, the application has to be responsive (no slow loadings) and user-friendly to use.
- **Network update**: It is compulsory to maintain the history of changes applied to the Road Graph and its attribute. The changes are applied only by the authorized personnel.
- **Queries executions**: The data collected and updated must be queryable, with the possibility to export the queries' results, for future analysis.
- **Map visualization**: The system must show the orthophoto map and the map.

2.1.2 Management of vertical signs

- **Signs management**: It is required to collect information about the road signs like type of sign, date of installation and many more. The possibility of removing or adding signals must be satisfied.
- **Police Consultation**: The road status must also be available to the police officers using the same application.

2.1.3 Management of inspections of the roads conditions

- **Management of roads state**: The system must collect the malformations of the road, along with the position and type of damage. It is also necessary to detect the damage to the road signs and the state of safety devices, like road lamps and traffic separators: these are very important to monitor because they could be damaged in case of car crashes, and they must be repaired or substituted.

2.2 Data requirements

- **Required Data**: Detailed overview regarding the roads managements of the province, including the spatial components, attributes that describe the situation (position of the road sign damages, extension of the damage) and historical changes applied to the road network.
- **Data Format**: The geographical must follow the ETRF2000 reference system in accordance with the national standards, with NC5 level of detail. The system must be able to work with all major OGC standard format exchange, i.e. the famous shape format, KML, GeoJSON (JSON version to deal with spatial data) and more. Working with all these OGC standards, the System will be able to work with existing and future technologies, guaranteeing interoperability among different systems.

2.3 Non functional Requirements

- **PostgreSQL DBMS**: among the FOSS Database Management Systems is required to use PostgreSQL along with the GIS component to deal with the spatial data.
- **FOSS Component usage**: The system has to be based on the use of Free and Open Source Software, for its development and future maintenance.
- **Compliance with the applicable standards**: The System must follow the guidelines drawn up by national and international bodies, like how to handle roads management in accordance with the standards and how data must be collected and handled.
  These procedures ensure data sharing and promote interoperability with other systems within the same domain.

3 Starting Situation

To really understand the project, it is important to look at the starting situation, including the technology, existing data, market analysis and constraints to satisfy.

3.1 Technology

The IT department of the city of Padova is in charge of the management of the information system using commercial software and the PostgreSQL database management system (DBMS).
However, a Geographic Information System (GIS) application for the management of the road network of the province is not currently developed: our goal is to build a customized GIS solution to fulfill the province's requirements.

3.2 Existing data

The Veneto region already has a topographic database which follows the national standard corresponding to the NC5 level, based on the ETRF2000 reference system. This database provides informations about the province's roads registry.
Additionally, an ortophoto map at a scale of 1:5000 is accesible through WMS non-transactional services.

3.3 Market analysis

There are currently no packaged solutions that meet all these requirements. Therefore there is a big opportunity to develop a solution that meets perfectly the city's needs.

3.4 Constraints

There are no particular time, monetary and business constraints.

4 Working Hypotesis

The following working hypotheses for the development of this project are based on a careful analysis of the requirements.

4.1 Considerations

The primary focus is to develop a robust and scalable road network system that perfectly meets the needs of the city of Padova. First of all, it is very important to follow the standards and applying best practices in roads management. Additionally, the system will be designed as an application compatible with commonly used browsers like Chrome and Firefox. There will be also functionalities for specific use cases that may require customization using desktop GIS tools.

4.2 Hypothesis

Implementing a customized GIS web application, integrated with a PostgreSQL DBMS, it is possible to create an efficient roads management system meeting the specified requirements. The system will enable the province to manage the following items: the road registry, the vertical signs and the inspections of the road conditions . To achieve this, the following key features are required:

- Import and export of data in GDF format and other standard formats (GML, shape) to facilitate integration with existing data sources.
- Update the graph and attributes of the network, while maintaining the possibility of saving the history of changes. In this way, a complete view of the roads network evolution over the time will always be available.
- A system of queries that combines spatial and alphanumeric filters to enable users to perform complex queries.
- Export of the query results to save and utilize the obtained data for future analysis.
- Visualization of the map and ortophoto in the background to allow the analysis of data within the system.

In addition to these fundamental features, the system will address specific requirements within the roads network domain. It will enable the province to:

- Management of road signs like knowing their locations and attributes, insert new ones or remove those eliminated by technicians.
- Detection and collection of the road conditions made by a specialized team. In particular is necessary to detect: the presence of malformations on the road surface, damage to road signs and damage to the safety devices.
- The data of the road registry, of the signs and the inspections can be consulted by the technical offices of the province.

4.3 Analysis of Risks and Constraints

Before the development of the project, an analysis of potential risks and constraints will be conduct to verify that some risks may affect the project's success. These could include technical challenges, data quality issues, resource limitations, and compliance requirements. To address these risks and ensure a regular project execution, mitigation strategies will be developed and executed.

5 Preliminary Project

This section provides an overview of the road management system project for the city of Padova. It covers various aspects like including goals, system functions, databases, technological components, project guidelines, operational aspects, risk management, benefits evaluation and cost evaluation.

5.1 Goals

To ensure the successful development, implementation, and utilization of the system, the road registry and road signs management project for the Municipality of Padova has defined specific goals. These objectives fall into two main categories: overarching goals and intermediate goals. They not only provide clear direction for our project team but also serve as quantifiable benchmarks to evaluate the project's overall success.

5.1.1 Overarching Goals

5.2 System overview

Here it will outlined the technologies, both hardware and software, used in desktop application and web application in the proposed system, to browse the information regarding the status of the road network for the Padova municipality.

5.2.1 Database

From the specification, it is known that the IT department uses the FOSS DBMS PostgreSQL: it is necessary to install the geography components PostGIS, in order to achieve the maintenance of the geographical information of the road status. The goal of PostGIS will be the spatial data handling for the road registry.

5.2.2 Desktop Application GIS System

For the Desktop application, the system must require the compliance of the use of FOSS software as non-functional requirement, like openJUMP, based on the JAVA JTS library, along with a JDK for the JVM utilization.
Mininum hardware requirements for the user's terminals will be given.

5.2.3 Web Application GIS System

The web application is composed by the following components:

- front-end application: this will be the available end-user interface to the system. The citizens will insert reports, while the technicians and the police officers will consult the status of the road status. Here a background map will displayed, along with the road network.
- back-end application: here the processing will take place: possibility of list all reports submitted, the report submission and more.
- database application: this part will store the information regarding the road network status.

5.2.4 Software Requirements

For the **openJUMP plugins** the following software technologies will be used:

- **openJUMP** software with the ad-hoc developed plugins.
- **JAVA VIRTUAL MACHINE** used by openJUMP.
- **PostgreSQL DBMS** and **DBMS connecto**r to access PostgreSQL data.
- **Ubuntu** as FOSS operating system in the user terminals.

The **Desktop Application** will utilised the following software technologies:

- **PostgreSQL DBMS** and **DBMS connector** to access PostgreSQL data.
- **PHP interpreter** to execute the PHP back-end code.
- the FOSS software **Apache HTTP Server** for publicing the Web Application.
- **JavaScript interpreter** for the front-end processing and for showing the background and road map.
- **HTML** as structure of the Web Application and **CSS** for the Web Application styling. The interpreter is the user browser.
- the FOSS JavaScript based library **OpenLayers**, for displaying the background map, using the FOSS map service **OpenStreetMap**.
- **GeoServer** with Web Map Service (WMS) to handle spatial data.
- **TomCat** (or other related software) application is necessary to run GeoServer on Java Container.
- **system firewall** and **proxy firewall** to manage unauthorized access to the internal system.
- **Ubuntu** as FOSS operating system used to run the Servers present in System.

5.2.5 Hardware Requirements

The hardware requirements for the System are:

- **Hardware for Web Server** hardware and UPS for managing access to the Web Application
- **Hardware for Geo Server** hardware and UPS for handling GeoServer software
- **Hardware for Database Server** for storing, accessing and modifying the data associated to the road network.
- **Hardware for Internal Server**: here will be provided functionalities for the Province Office, like shared printers.
- **Office terminals**: a terminal with 8 GB or RAM and base line Intel Core i5 from the 13^{th} generation will be enough to access the Desktop Application functionalities.
- **no** specifics **hardware requirements are needed by the end users** for accessing the Web Application.

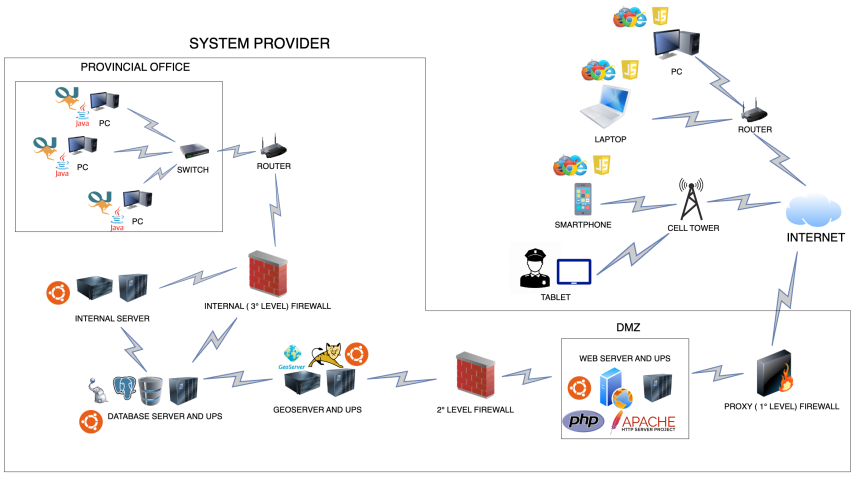

Figure 1: System schema

5.2.6 System Schema

Core functionalities of the System:

- **three level of firewall** for ensuring maximum security. The first level is the proxy firewall to check the incoming connection, the second one handles the access to the GeoServer and Database Server. The third one is used internally from the office technicians to access the servers.
- **DMZ** (Demilitarized Zone) is the only area accessible from the public users, hence must be protected by the proxy firewall to ensure "safe" access.
- **UPS** (Uninterruptible Power Supplies) used to ensure continual power supply to the servers of the System, even when the main power supply fail.

5.3 Functionality of the System

In this section will be outlined the core functionalites of the Web Application and of the plugins developed for openJUMP.

5.3.1 Web Application

The Web Application developed is used by the citizens of the Padova municipality for signal the presence of malformations in the road network, and used by the technician of the Provincial office to visualize which reports have been submitted by the citizens.

- **HOMEPAGE**

  In the homepage, it is possible to see the map displaying the road network of Padova municipality. The user to submit the report must insert the position by clicking on the map or by using the GPS coordinate of the device. In the second figure is present the report form for the submission.

- **LOGIN PAGE**

  To manage unauthorized users, the system is provided of an authentication mechanism made available by the login page; only the technician of the provincial office and the police officers can access to the restricted area by performing the login operation.

- **LIST REPORTS** In this restricted area is possible to visualize all report submitted filtered by year. From the page the operator can decide to visualize one or all reports of the selected year.

- **SHOW REPORT** Here it is possible to visualize a specific submitted reports with its positions and all details specified by the citizens in the report.

- **SHOW REPORTS** In the show reports page we can see all the submitted reports for the specified year, as a pin in the map. By clicking on the marker it is possible to see a short preview of the report, and by clicking the button to go to the show report page to get full informations about that report.

5.3.2 openJUMP plugins

5.4 Database

5.4.1 ER Schema

5.4.2 Description of the Entities and the Relationship of the ER Schema

6 Project Guidelines

6.1 Cost analysis

In this section, they will be outlined the cost of developing GIS system previosly described. Into the making of a project, there two types of cost: the cost of the project itself, plus costs that are needed to maintain and renew the system.

6.1.1 Project cost

In the table below, there three types of costs:

- **technician cost**: this $30 unit cost is associated to one hour of work from an external technician to setup one of the three servers.
- **WebApp developer cost**: $70 is the amount of money that the developer of the Web Application will receive for one hour of work.
- **Java developer cost**: $46 is the amount of money that the developer of the openJUMP plugins will receive for one hour of work.

Table 1: Project Cost Breakdown

Activity	Unit cost	Quantity	TOTAL
Web Server configuration	30	24h	$720,00
DB Server configuration	30	21h	$630,00
Geo Server configuration	30	22h	$660,00
DB creation	30	8h	$240,00
Table creation	30	12h	$360,00
Webapp development	70	248h	$17,360,00
Plugins development	46	96h	$4,416,00
Webapp testing	70	56h	$3,920,00
Plugins testing	46	48h	$2,208,00
Webapp deployment	70	16h	$1,120,00
Plugin deployment	46	16h	$736,00
Web Server deployment	30	40h	$1,200,00
DB deployment	30	49h	$1,470,00
Geo Server deployment	30	40h	$1,200,00
TOTAL			$36,240,00

6.1.2 Running costs

In the running costs table, there two types of costs: the one regarding the Server maintenance that it is carried out once year and its fixed, and the cost associated to the assistance, which it depends on how many hours a year a technician on-site o remotely, will be necessary for troubleshooting.

Table 2: Project Cost Breakdown

Activity	Unit cost	Quantity	TOTAL
Server maintenance	1500	1	$1500,00
Remote assistance	20	X	$20*X
On-site assistance	30	X	$30*X
TOTAL			$1500,00 + variable cost