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Functional Modeling of a Web-Based GIS for Sustainable University Infrastructure Management: A Case Study of Jean Lorougnon Guede University, Côte d'Ivoire

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Abstract

Digital transformation in higher education has become a key driver for improving academic and organizational performance. In Côte d'Ivoire, despite recent progress, the daily management of university infrastructure remains affected by room allocation conflicts, underutilization of classrooms, and limited coordination among stakeholders. This study proposes a functional model based on a Web-based Geographic Information System (WebGIS) to optimize the spatio-temporal management of teaching infrastructure at Jean Lorougnon Guédé University (UJLoG). Functional requirements were formalized through functional analysis using the "horned beast" diagram and system decomposition with FAST diagrams. The proposed platform, UJLoG-Hub, relies on object-oriented building classification, UML modeling, and the implementation of a WebGIS prototype based on PostGIS, GeoServer, JavaScript, and OpenLayers. Results demonstrate improved dynamic visualization of infrastructure, reduced scheduling conflicts, enhanced course planning, and more sustainable use of university resources.

Keywords: WebGIS; UML; Object-oriented modeling; University infrastructure management; Côte d'Ivoire

1. Introduction

Digital technologies are reshaping university systems worldwide by fostering new modes of management, learning, and organization across all sectors of society and academic activities [1, 2]. In Côte d'Ivoire, this transformation is accompanied by a rapid increase in student enrollment, particularly within public universities. Established in 2012 [3], Jean Lorougnon Guédé University (UJLoG) primarily delivers face-to-face instruction while progressively integrating digital tools into its academic and administrative activities.

Despite this adoption of digital technologies, the management of teaching infrastructure remains affected by room allocation conflicts, underutilization of classrooms, a lack of real-time traceability, and insufficient coordination among stakeholders. The introduction of Web-based Geographic Information System (WebGIS) technologies provides a relevant response to these challenges, due to their ability to represent and analyze spatial and temporal data through interactive interfaces. In particular, WebGIS solutions enable the monitoring of room occupancy, the automation of course scheduling, and improved communication among academic planners and administrators.

In this context, the objective of this research is to develop a spatio-temporal WebGIS platform model aimed at sustainably improving the teaching management system at UJLoG. Specifically, the study seeks to:

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- Identify and structure the functional requirements of the infrastructure management system through functional analysis;
- Model system processes, data, and interactions using UML diagrams in preparation for the development of the WebGIS platform.

1.1. Study Area

UJLoG is located in the Daloa Department, Haut-Sassandra Region, in the central-western part of Côte d'Ivoire. The study area lies between longitudes 6°26′53.413″ and 6°25′15.221″ West, and latitudes 6°54′17.884″ and 6°55′54.953″ North.

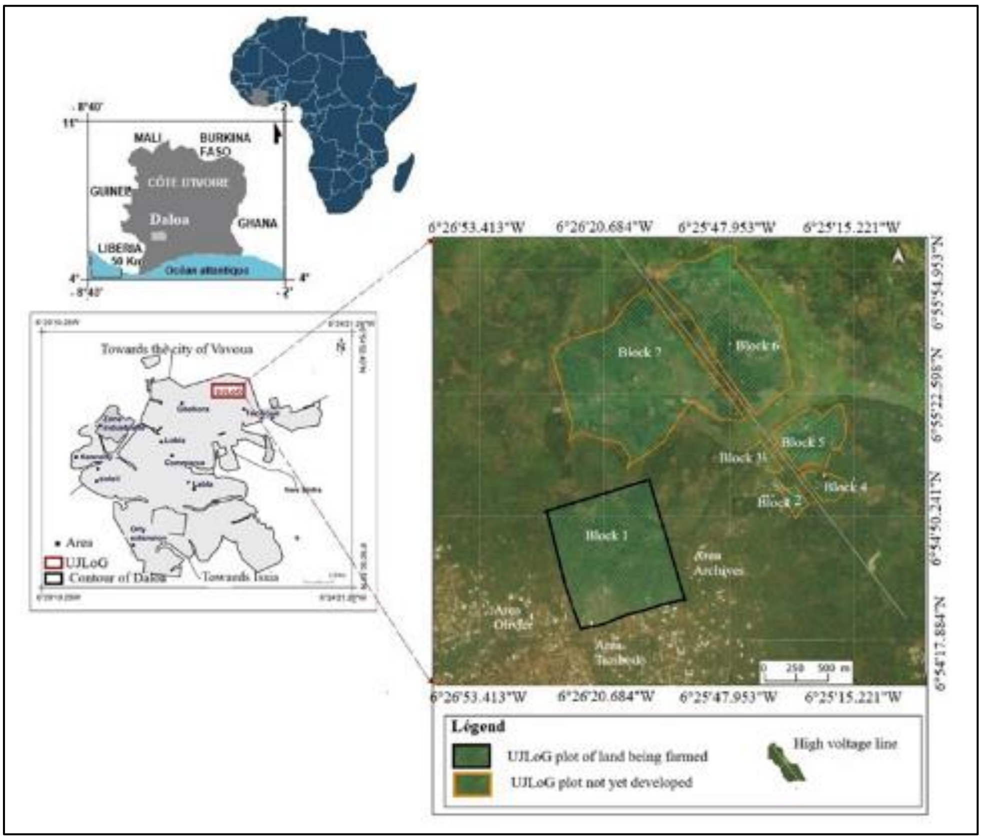

Figure 1 Study area

1.2. Mission and Resources

UJLoG is administered through three governing bodies [4]: the Management Council, the University Council, and the President, who is responsible for the overall administration and strategic orientation of the institution. The university's primary mission is to provide both initial and continuing education through five Training and Research Units (UFRs), encompassing the fields of agroforestry, environment, law, economics and management, and social sciences. In addition, UJLoG operates a Continuing Education Center (CEC) aimed at enhancing professional skills and lifelong learning.

As of 2025, UJLoG enrolls approximately 4,600 students supervised by 515 academic staff members (Human Resources Department, 2025). The teaching infrastructure (see Figure 2) consists of four (4) lecture halls, three of which have a seating capacity of 530 students each, while the remaining hall accommodates up to 250 students [5]. These facilities are primarily dedicated to lecture-based teaching. Furthermore, the university has five (5) buildings specifically designed to host tutorial sessions and practical laboratory work (TD and TP).

SW: Supervised Works – LW: Laboratory Works

Figure 2 Example of teaching infrastructure at UJLoG

2. Material and methods

2.1. Materials

The material used in this study is centered on a portable microcomputer equipped with an Intel Core i7 processor and 16 GB of RAM, along with the PowerAMC software for the design and implementation of UML diagrams.

2.2. Methods

The methodology is based on the integration of functional analysis, computational modeling, geographic data structuring, and WebGIS development.

Functional Analysis ("Horned Beast" Diagram)

The "horned beast" diagram is used to characterize the service functions expected from the system [6, 7]. This diagram supports the design of a digital tool intended to enable academic and administrative stakeholders to manage, consult, and optimize the use of teaching infrastructure. The formulation of system requirements is guided by three fundamental questions:

- Who does the system serve ? Academic and administrative stakeholders.
- What does the system act upon ? Teaching infrastructure, schedules, and geospatial data.
- For what purpose ? To improve, simplify, and secure infrastructure management.
- Functional Decomposition (FAST Method)

The FAST diagram (Function Analysis System Technique) is a graphical tool used to detail technical functions and their associated solutions [8, 9]. The diagrams were produced using the PowerAMC CASE tool. Three FAST diagrams were developed in order to organize system functions into logical chains aimed at:

- Accessing infrastructure-related information, including data integration, updates, geographic formats, and coordinate reference systems ;
- Integrating the management methodology by taking into account actors, circulation paths, room capacities, and scheduling rules ;
- Disseminating results through cartographic visualization, charts, data export, navigation, search, and printing functionalities.

These diagrams facilitate the identification of appropriate technical solutions and contribute to a structured system design.

2.3. UML Modeling

The Unified Modeling Language (UML) has been adopted by several researchers for the development of complex information systems, particularly in the environmental domain [10-14]. It is therefore well suited for modeling spatially related problems.

In the context of the present study, UML modeling is structured around three main types of diagrams:

- Use case diagrams ;
- Activity and sequence diagrams ;
- Class diagrams.
- UML provides a clear understanding of the interactions among actors, system functions, and internal processes.

3. Results

3.1. Functional Analysis

"Horned Beast" Diagram

Figure 3 illustrates the developed platform. It represents a digital system designed to centralize and streamline the management of the university's teaching infrastructure. The platform addresses a clearly defined operational need: to provide the entire university community (administration, faculty, staff, and students) with a unified tool for planning and cartographic visualization of classrooms and teaching-related spaces.

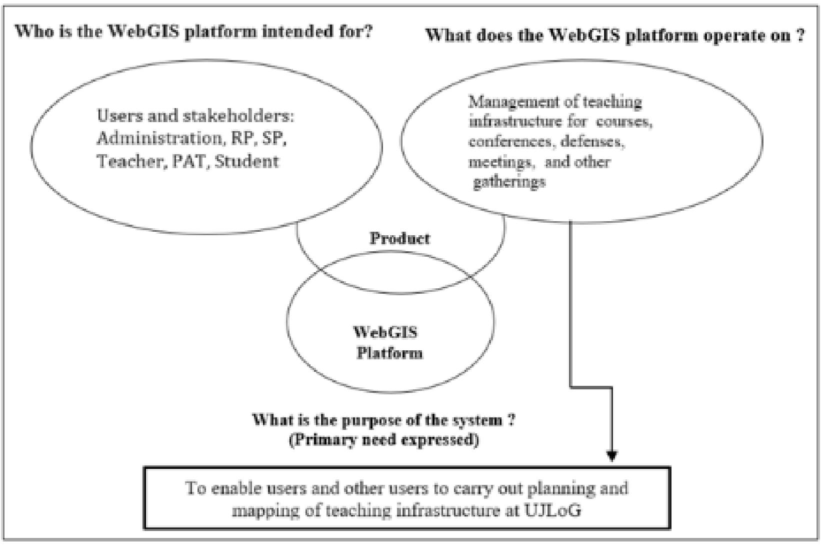

Figure 3 "Horned Beast" diagram

The diagram highlights the specific role of the platform as an intelligent intermediary between users and physical resources. It automates room reservation processes and provides real-time visibility of space availability for courses, meetings, thesis defenses, and other academic activities. Ultimately, UJLoG-Hub transforms space management from a fragmented logistical process into a fluid, transparent, and accessible system that supports the institution's organizational efficiency.

3.2. FAST Diagram

The FAST diagram presented in Figure 4 structures the main function related to access to information on teaching infrastructure, combined with the integration of an analytical method.

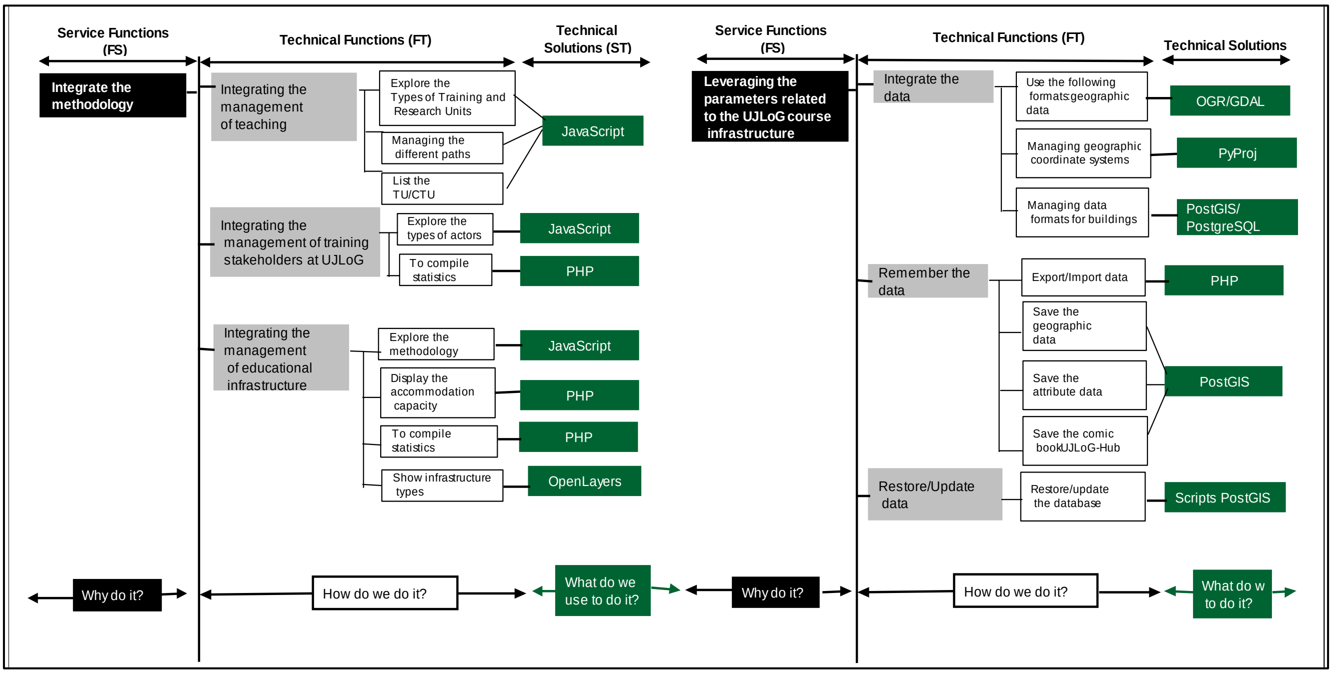

Figure 4 FAST diagram for access to information related to teaching infrastructure and integration of the analytical method

This diagram decomposes the main function into operational sub-functions and links each of them to appropriate technical or organizational solutions. The FAST diagram shown in Figure 5 illustrates the different main functions of the system and their respective interactions.

FAST analysis enabled the modeling of two key processes: (1) access to and integration of educational infrastructure data, and (2) dissemination of analytical results. This approach ensures complete functional traceability, from user requirements to technical solutions. It promotes a user-centered design and a structured methodological integration. The produced diagrams clearly represent the operational steps and the required support mechanisms associated with each function.

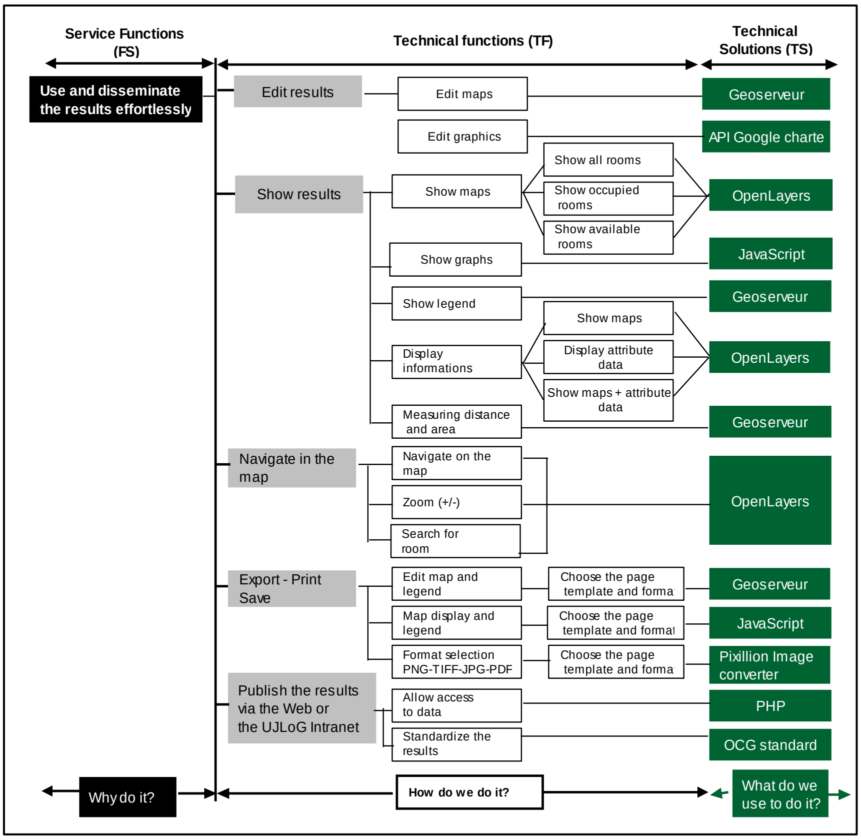

Figure 5 FAST diagram for the main function: dissemination of results

3.3. Actors and Use Cases

Actors

Four groups of primary actors were identified (Table I).

Table 1 System Actors

Actors	Roles
Program Coordinator (PC)	Schedules courses
Senior Secretary (SS)	Validates course schedules Allocate infrastructures (amphitheater and classrooms) Notifies instructors and students
Governance (GOV)	Monitors the progress of teaching activities Monitors the occupancy status of buildings
Platform Administrator (ADM)	Supervises and manages the platform

3.4. Use Case

Figure 6 illustrates the use case referred to as the “general use case.” It involves nearly all users who access the system after authentication in order to perform one or more tasks executed by the information system.

This use case diagram illustrates the interactions between an authenticated user and the future UJLoG-Hub platform. Once logged in, the user will be able to perform one or more actions, which will trigger processing by the system. These interactions will take the form of queries, to which the platform will respond by displaying relevant results. Planned functionalities will include map navigation, information search, and data or map export, among others. This use case provides a forward-looking overview of the platform's intended operational capabilities.

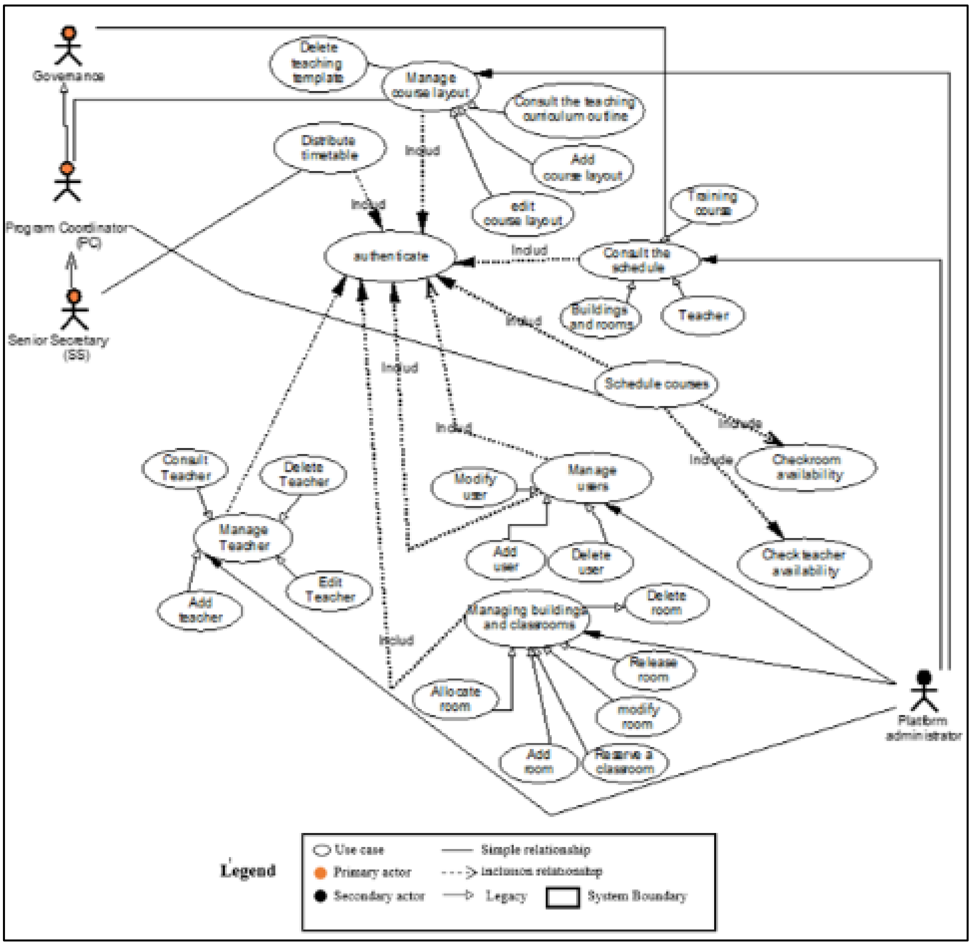

Figure 6 General use case diagram of the platform

Through this use case, users interact with the platform by submitting queries. The system displays results according to the actions performed by the user. These results may include map navigation, information retrieval, data or map export, among others. This use case provides an overall view of the platform's functionalities and the actors involved in teaching planning and infrastructure management.

3.5. Dynamic Model: Activity Diagrams

For critical Use Cases (UCs), such as Schedule Course and Reserve Room, activity diagrams were developed. For instance, the Activity Diagram (AD) associated with the Schedule Course use case models decision points (decision nodes) and parallel flows (fork nodes) between the verification of room availability and instructor availability, thereby ensuring the absence of scheduling conflicts prior to validation (see Figure 7). This diagram illustrates also a well-structured course planning process, beginning with a secure login to the system. It then follows a logical sequence of checks for parameters and the availability of necessary resources. Considering the room and the instructor ensures consistency and avoids scheduling conflicts. A clear legend facilitates understanding of the different types of actions and decisions. The whole forms a complete and organized workflow, suitable for academic management.

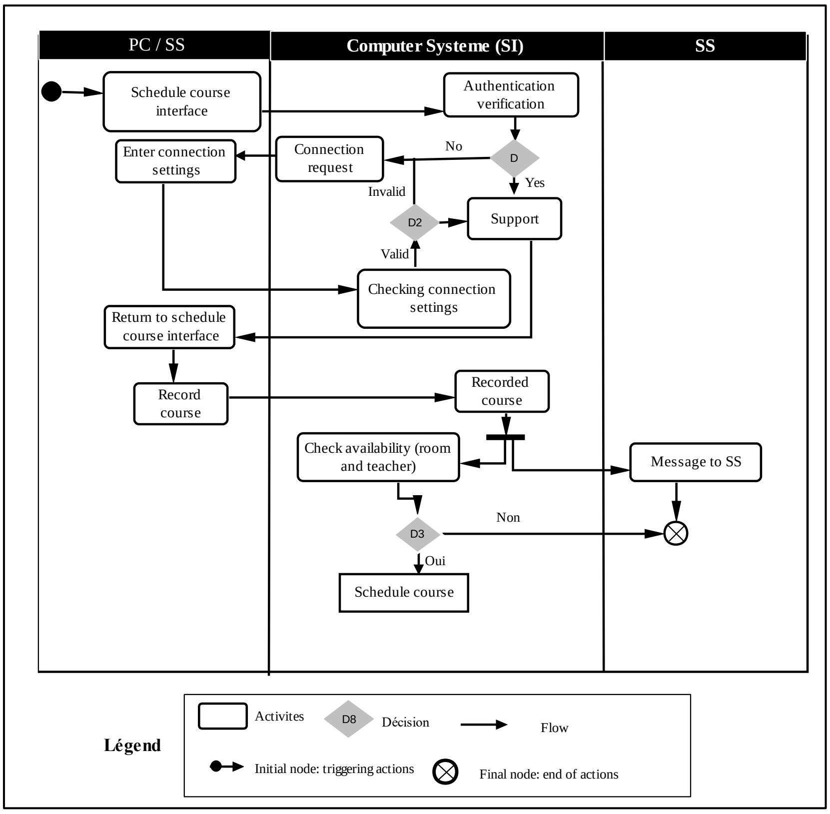

Figure 7 Activity diagram for course scheduling

3.6. Static Modeling: Class Diagram

The core of the proposed model is represented by the class diagram (see Figure 8). This diagram highlights the cartographic representation of teaching infrastructure at UJLoG. The generated maps support two main usage modes: course reservation for teaching activities through the "Allocate_course" class, and other types of activities through the "Free_allocation" class.

Two principal classes characterize the cartographic model of teaching activities, namely the "Infrastructure" and "Map" classes. The "Infrastructure" class groups all attributes required to generate teaching infrastructure maps. The "Map" class is defined by its scale, the longitude and latitude of its lower-left corner, as well as the height and width of the area covered by the map. In addition, each map contains a set of heterogeneous geographic data.

Furthermore, each generated map includes essential cartographic elements such as scale, Legend, and geographic north orientation.

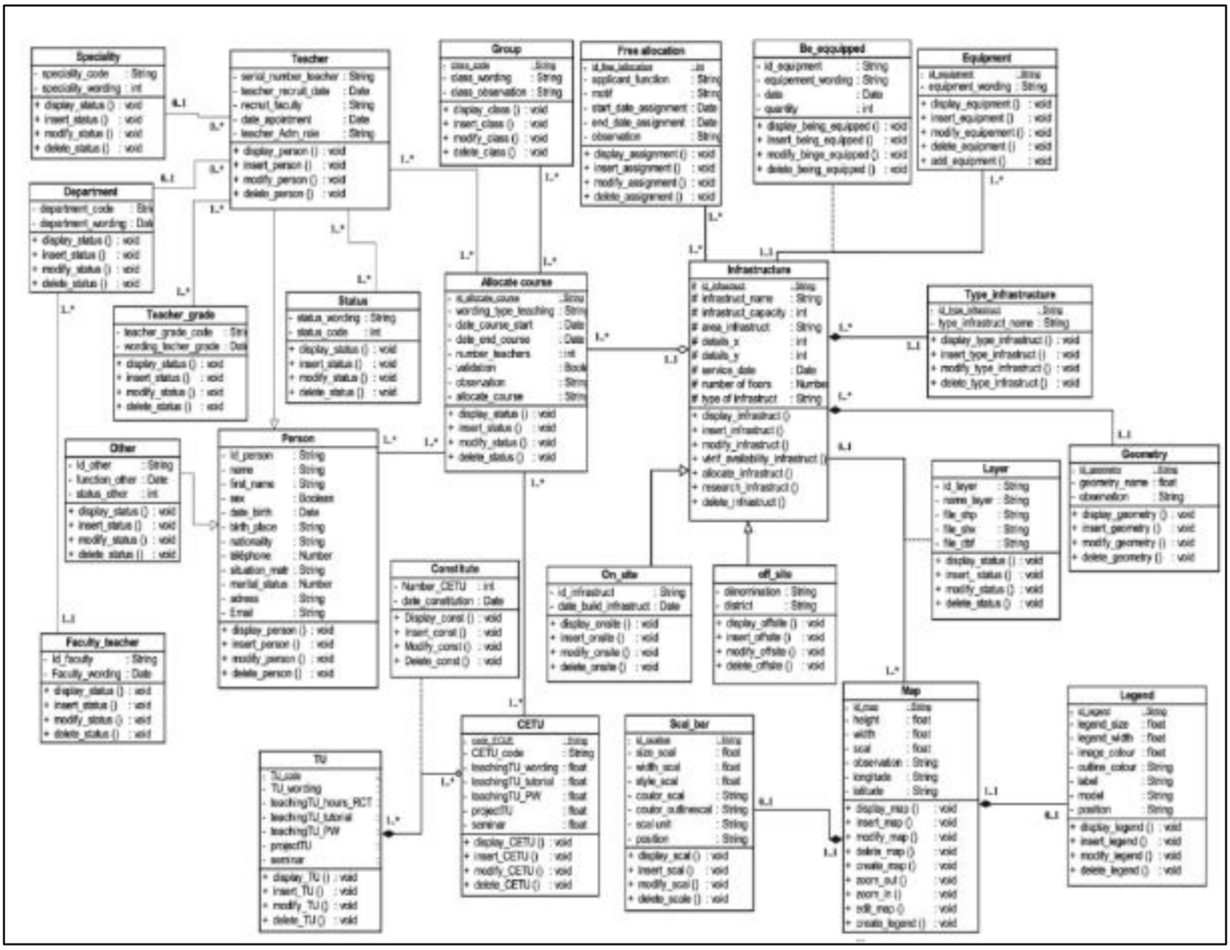

Figure 8 Class diagram representing the model

4. Discussion

4.1. Functional Analysis and Decomposition

The “horned beast” diagram effectively fulfills its primary role, which is to define the scope and purpose of the system in a simple and understandable manner. It represents an excellent starting point, provided that it is complemented by additional analyses to ensure a user-centered, feasible, and sustainable system design [7, 15].

The analyzed FAST diagrams highlight a rigorous functional approach that structures the design of the educational infrastructure management system around two interdependent axes [8]: data access and analytical value creation. These diagrams provide a solid and integrated methodological framework for designing an educational infrastructure management system that is operational, user-centered, and decision-oriented.

They therefore constitute a precise functional foundation for both technical and organizational deployment, on the condition that they are supplemented by a feasibility analysis and a detailed implementation plan.

4.2. UML Model

This work highlights the relevance of key concepts of the UML modeling language for the representation of complex systems, particularly in the context of territory management and spatial analysis [13, 14, 16]. The class diagram enabled the design of a rich Conceptual Data Model (CDM), integrating both business entities and their implicit spatial relationships, such as location and contiguity.

The semi-automatic generation of the Logical Data Model (LDM) from PowerAMC reduced the risk of inconsistencies between design and implementation phases [17]. The organization of the model into packages reflects a clear separation of business responsibilities, thereby facilitating system maintenance and future evolution. This modularity, for instance, allows modifications to actor management processes without impacting infrastructure management components.

The main challenge encountered concerned the modeling of fine-grained temporal constraints, particularly scheduling overlaps, at the static level of the class diagram. These constraints were subsequently addressed within the business logic layer through stored procedures. A recommended best practice would be to further enrich the model by incorporating state-transition diagrams for Room objects, with states such as available, reserved, and occupied.

5. Conclusion

This work demonstrates the applicability and usefulness of a systematic UML modeling approach for the design of a university WebGIS. The proposed model, centered on a robust class diagram and explicit behavioral diagrams, provided a clear and shareable conceptual foundation among stakeholders, including users and developers. It directly guided the development of the spatial database and the functional modules of the UJLoG-Hub application.

Beyond the specific case of UJLoG University, this modeling approach offers a reusable framework for the design of information systems that integrate both geographic and temporal dimensions, particularly in the field of educational resource management.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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