



## Design of a Web-Based E-Library Using the Model-View-Controller (MVC) Architecture for Aviation Vocational Education

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### Abstract

The governance of instructional documents and specialized reference materials in aviation vocational education requires a repository system that ensures high data integrity, low access latency, and adaptive scalability. This study aims to design and develop a web-based electronic library (e-library) system specifically optimized for the Air Traffic Management Study Program. To overcome the limitations of conventional monolithic architectures, which are prone to data redundancy and integrity issues, the proposed system was developed using the System Development Life Cycle (SDLC) with the sequential linear (Waterfall) model and implemented through the Model–View–Controller (MVC) architectural pattern using the Laravel framework. The relational database environment was managed using MySQL Server with optimized implementation of Data Definition Language (DDL) and Data Manipulation Language (DML). The functional quality and system behavior were comprehensively evaluated using the Black Box Testing method with an equivalence partitioning approach. The results demonstrate that restructuring the database into an MVC-based e-library platform not only eliminates the risk of physical document loss and unauthorized manipulation of instructional data but also significantly reduces the time required to retrieve Air Traffic Control (ATC) reference materials through automated digital document indexing. Functional testing confirmed that all file management modules (add, edit, and delete) as well as user authentication functions achieved a 100% success rate. These findings indicate that the proposed system serves as a robust foundation for supporting digital academic knowledge management in higher vocational education.

**Keywords:** Digital Repository, E-Library, Model–View–Controller (MVC), Laravel Framework, Software Engineering.

### INTRODUCTION

The rapid advancement of information technology in the era of the Fourth Industrial Revolution (Industry 4.0) and Society 5.0 has fundamentally transformed the paradigm of higher education, particularly within vocational and government-affiliated educational institutions. In highly specialized academic programs such as Air Traffic Management (ATM), the availability of up-to-date instructional materials, international aviation regulatory documents—including the International Civil Aviation Organization (ICAO) Annexes—and Air Traffic Controller (ATC) operational manuals is indispensable. Managing these academic knowledge assets requires a robust digital repository platform, as aviation operational documents are subject to continuous amendments and periodic revisions.

The vocational curriculum of the Air Traffic Management Study Program is characterized by its strong dependence on global regulatory compliance. Consequently, instructional resources extend beyond static educational materials to encompass dynamic representations of international aviation regulations embedded in operational safety standards and procedures. Whenever international aviation authorities issue amendments concerning airspace management or performance-based navigation, both classroom instruction and simulator-based training materials must be updated promptly. This synchronization is essential to prevent knowledge gaps between theoretical instruction delivered in academic settings and its practical implementation within operational air traffic service units.

From a knowledge management perspective, aviation operational documents are classified as explicit knowledge assets with a high degree of sensitivity to chronological validity. Therefore, a robust digital repository should function not merely as a storage medium but as a comprehensive document lifecycle management system that incorporates strict and automated version control mechanisms. Within

an integrated information system architecture, whenever new regulatory documents or aviation safety practicum modules are uploaded, the relational database should automatically archive previous versions without deleting them while designating the latest version as the single source of truth accessible to cadets. This approach is essential for preserving the historical traceability of regulatory amendments, minimizing data redundancy within the server environment, and ensuring that cadets consistently access the most current operational procedures rather than relying on deprecated navigation guidelines.

The digital transformation toward a web-based e-library platform with a centralized architectural model provides levels of data availability and integrity that cannot be achieved through conventional storage methods. In the context of vocational aviation education, where simulator-based training schedules are intensive, cadets require ubiquitous access to instructional resources, enabling secure retrieval of information anytime and from any device while reducing information silos caused by fragmented document storage. By leveraging a centralized Database Management System (DBMS), the study program can enforce strict access control policies, whereby document management operations—including the creation, modification, and deletion of regulatory amendments—are restricted exclusively to authorized administrators, such as instructors and librarians, through server-side authorization mechanisms. In contrast, cadets are provided with a dedicated data access pipeline optimized for high-performance indexed searching and secure document retrieval. This architecture establishes a reliable and secure digital learning ecosystem that minimizes the risk of information leakage while ensuring continuous support for internationally standardized aviation vocational education.

Conventional document management, which relies on physical (hardcopy) storage, is inherently constrained by material and logistical limitations that increase operational costs and the risk of physical deterioration. Paper-based records are particularly vulnerable to environmental factors such as humidity, termite infestation, and physical disasters, including fire, all of which may result in the permanent loss of critical instructional documents. Beyond the durability of the storage medium, the inefficiency of text retrieval represents another major limitation of manual library systems. Users are typically required to search through physical catalogs or archived documents individually, making the retrieval process time-consuming and poorly suited to the rapid information access demands of the digital era. Furthermore, manual lending systems based on ledger books or physical control cards often lack accurate and reliable tracking mechanisms, making it difficult for librarians to identify current borrowers and increasing the likelihood of document loss due to inadequate monitoring and return control procedures.

From the perspectives of software engineering and information systems management, the absence of a centralized database gives rise to information silos, in which critical data are isolated across individual staff or instructors' personal computers without synchronized data exchange. This fragmentation directly weakens access control mechanisms, as no digital authentication framework is available to verify whether a user is authorized to view, copy, or modify operational documents. Within vocational education institutions that require a high degree of standardization, such fragmented and manual document management procedures create significant workflow bottlenecks, hindering knowledge dissemination while increasing the risk of unauthorized record manipulation. Without a secure centralized database serving as the single source of truth, institutions cannot achieve standardized operational services, enforce information security compliance, or provide academic services that are transparent, reliable, and maintain a high level of data integrity.

To address these functional gaps, a web-based electronic library (e-library) architecture founded on modern software engineering principles is proposed. A web-based platform was selected due to its cross-platform compatibility, efficient utilization of computing resources, and ability to handle simultaneous client requests through an internet-based request–response architecture. The scientific novelty of this study lies in the structured integration of aviation document governance into a relational database environment using the Model–View–Controller (MVC) architectural pattern. By separating business logic from the presentation layer, the MVC architecture enhances system maintainability while improving data security against information leakage and unauthorized document manipulation. Accordingly, this study aims to provide a comprehensive description of the design, development, and implementation of the proposed e-library system for the Air Traffic Management Study Program, covering the conceptual design, software architecture, code organization, and functional evaluation of the developed software system.

## **METHOD**

This study adopted an object-oriented software engineering methodology based on the System Development Life Cycle (SDLC) using the Waterfall development model. The sequential linear approach was selected because the development of the proposed e-library system requires a stable and well-defined data architecture, a structured development process, and comprehensive documentation throughout each stage of the software lifecycle. The implementation of the SDLC methodology in this study is described in detail through the following phases.

1. **System Requirements Analysis Phase**  
 The initial phase focused on gathering data on functional and non-functional requirements. The functional analysis includes user access rights specifications, which are divided into two roles: Admin (Program Staff/Librarian) and User (Student/Faculty). Non-functional requirements emphasize system performance in the Google Chrome browser, multi-platform compatibility, and database password encryption security.
2. **Software Architectural Design Phase**  
 This phase models data flows and relationships between digital entities. The system architecture is modeled using System Flowcharts and Entity-Relationship Diagrams (ERDs) to conceptualize the relational database structure. The user interface is designed using the Bootstrap CSS framework to ensure that the web menu layout is responsive when accessed via mobile devices or desktop computers.
3. **System Coding Phase (Implementation & Coding)**  
 The logical design was translated into executable source code using the latest version of PHP in conjunction with the Laravel framework. Laravel fully implements the Model–View–Controller (MVC) architectural pattern, in which:
  - a. **Model:** Defines the data schema and interacts directly with the database server through the Eloquent Object–Relational Mapping (ORM) framework.
  - b. **View:** Presents the graphical user interface to end users using the Blade Template Engine.
  - c. **Controller:** Acts as the intermediary layer that processes incoming HTTP requests, validates user input, executes the required business logic, and generates the appropriate HTTP responses.
4. **System Testing Phase (Software Testing)**  
 The system that has been developed was tested on a local server environment (localhost) using XAMPP (Apache Web Server and MySQL Server). The testing technique employed the Black Box Testing method, focusing on testing the program’s external functionality without examining the internal structure of the code. Test cases were designed using equivalence partitioning to verify the system’s correct response to form text inputs, button functions, PDF file upload management, and the encrypted login security system.

## RESULTS AND DISCUSSION

### Discussion of Relational Database Architecture (MySQL)

This e-library database system is designed using the MySQL relational database to ensure data consistency and referential integrity. Data structure management is strictly controlled through the implementation of structured SQL queries, which are divided into three functional domains:

1. **Data Definition Language (DDL)**  
 DDL is used to construct the data table schema within the database server. The main structure of the database consists of the users table (which stores user account data) and the documents table (which stores digital file metadata). The implementation of DDL programming queries is outlined in Table 1.

**Table 1.** Implementation of Data Definition Language (DDL) Statements

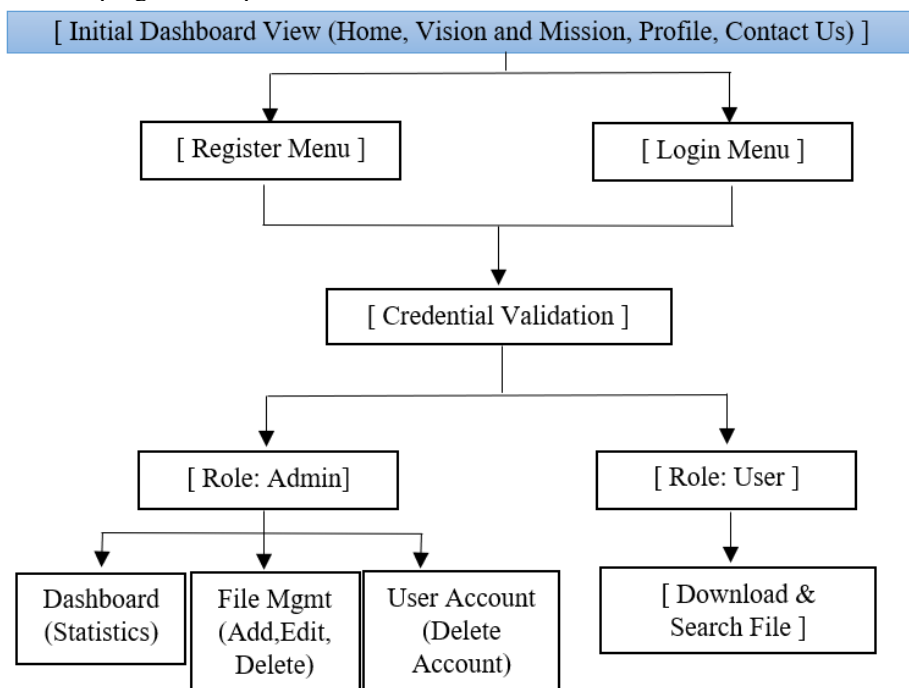
DDL Command	System-Specific Function	Primary Data Attributes
CREATE DATABASE	Creates the primary database repository for the study program's e-library system.	db_elibrary_mllu
CREATE TABLE users	Defines the database structure for user account management and system access control.	id (PK), name, username, password, role
CREATE TABLE documents	Defines the metadata structure for digital aviation reference documents.	id (PK), title, file_path, description, created_at
ALTER TABLE	Modifies existing database structures by adding indexes or foreign key relationships.	Addition of a search index on the title column

2. **Data Manipulation Language (DML)**  
 DML plays a role in processing data object manipulations within tables that occur dynamically when the web application is used by administrators or users. An INSERT query is executed by the system when an administrator uploads a new document or a user registers an account. An UPDATE query is executed when an administrator corrects document metadata on the interface form, while a DELETE query is used to remove data entities from database records. DML commands are systematically summarized in Table 2.

**Table 2.** Implementation of Data Manipulation Language (DML) Commands

DML Operation	User Interface (UI) Operation	Impact on the Database System
INSERT INTO	Add Files and User Registration forms	Inserts new records for digital documents or user accounts into the database.
UPDATE	Edit Document form	Updates existing document attributes, such as the title or description.
DELETE FROM	Delete Document / Delete Account button	Permanently removes document or user account records from the database.

3. Data Control Language (DCL)  
 DCL is used to control database access privileges. The GRANT command is issued to the backend system controller module to perform database operations, while the REVOKE command ensures that user accounts with the “user” role level (trainees) have absolutely no direct access to call database modification functions via an external console.
4. System Behavior and Workflow Analysis  
 This online library system divides system authorization into two main user roles to ensure the security of the academic program’s important document assets:



**Figure 1.** System Workflow

**Administrator Role (Librarian / Program Staff)**

The administrator has the highest authority for knowledge management. Upon logging into the admin dashboard, the system will run a data aggregation query to display statistics on the number of files uploaded. Through the File menu, the administrator can add documents by uploading files with the extensions .pdf, .docx, or .xlsx. If there are updates to the aviation curriculum materials, the admin simply clicks the Edit Data button, uploads the latest revised file, and clicks Save. The old files in the server directory folder are automatically replaced with the new files (V2, V3, etc.), thereby preventing duplicate data storage and ensuring that cadets always have access to the latest, valid documents.

**User (Student) Role**

Users have access restrictions to protect the integrity of system data. Students are not allowed to create accounts with the same username (unique constraint validation), cannot edit program metadata, and do not have the right to upload files to the server. The user’s main menu is focused on information retrieval, where students can perform text-based searches (string search matching) in the document search input field, then download reference documents directly to their device’s local storage via a secure streaming download controller module.

**Results of Functionality Testing and System Validation**

The functionality of the digital library system was validated using Black Box Testing scenarios. The test results confirmed that all components—including menu controls, input forms, login session validation, and

file upload/download handling—functioned successfully, with no system bugs or error-handling failures detected. Details of the system functionality test matrix are outlined in Table 3.

**Table 3.** Implementation of Data Manipulation Language (DML) Commands

Interface Component	Test Action (Input)	Observed System Response (Output)	Validation Status
Public Navigation Menu	Click the Home, Vision & Mission, Profile, and Contact Us navigation links.	The Laravel router correctly maps the requested URLs and renders the corresponding static views responsively.	Passed
User Registration Form	Leave the Name, Username, or Password fields empty and click Sign Up.	The system rejects the request, triggers form validation errors, and displays appropriate warning messages to the user.	Passed
User Registration Form	Complete all required fields with valid data and click Sign Up.	The controller executes an INSERT query to create a new user account, encrypts the password, and displays a successful registration message.	Passed
User Login Authentication	Enter a valid username and password combination.	The system validates the credentials, establishes a user session, and grants access to the main dashboard according to the assigned user role.	Passed
Document Search	Enter a document title keyword (e.g., "MATS") in the search field.	The controller executes an SQL SELECT query with the LIKE %keyword% clause and returns the relevant document list accurately.	Passed
Document Management (Administrator)	Click Add File, upload a PDF document, and click Save.	The uploaded file is stored in the local server directory, while its metadata are indexed and saved in the MySQL database.	Passed
Document Update	Click Edit, modify the document title, and click Save.	The system updates the existing record using an UPDATE query and refreshes the document list immediately.	Passed
Document Deletion	Click the Delete (X) icon for a selected document.	The system displays a confirmation dialog, removes the record using a DELETE query, and deletes the corresponding physical file from the server.	Passed
User Management (Administrator)	Open the User Accounts menu and delete a selected user account.	The system removes the user account from the database, thereby revoking the user's access privileges.	Passed
Session Termination	Click the Sign Out button from the dashboard.	The system invalidates the active user session and redirects the user to the public login page.	Passed

## CONCLUSION

The implementation of a website-based online library (e-library) technology in aviation vocational education has proven capable of transforming the management of academic documents into a much more structured, secure, and efficient system. The application design, which adopts the Model-View-Controller (MVC) architecture pattern using the Laravel framework, has proven reliable in separating the processing logic of the MySQL relational database from the user interface. A clear division of access permissions between Admins and Users has successfully addressed the vulnerabilities of conventional systems, eliminated the risk of losing critical air traffic operational documents, and prevented the manipulation of academic records by external parties. Based on the results of a comprehensive evaluation using Black Box Testing, all functional components of the system—including the data management module (DDL & DML), the login authentication system, text-based search indexing, and the data download function—have been proven to operate optimally with a 100% success rate. This digital repository system is ready to be integrated into the institution's web server network infrastructure to support a sustainable digital learning ecosystem.

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